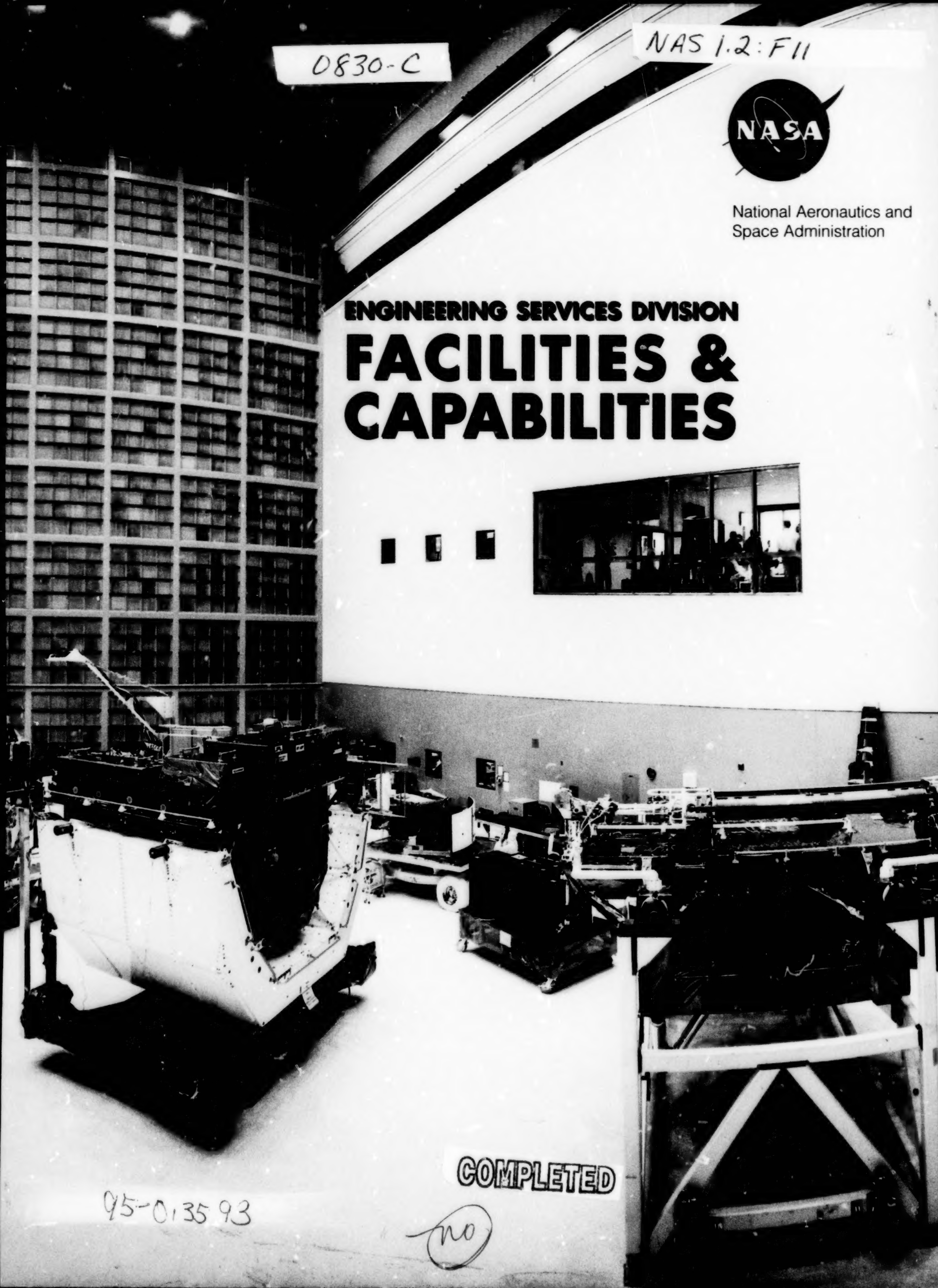
National Aeronautics and
Space Administration

ENGINEERING SERVICES DIVISION
FACILITIES & CAPABILITIES



JANUARY 1995

ENGINEERING SERVICES DIVISION

FACILITIES AND CAPABILITIES

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

Cover Photo: Spacecraft Systems Development And Integration Facility (SSDIF) Building 29 Cleanroom containing Hubble Space Telescope First Servicing Mission hardware returned from space. Panoramic photo by Dave Orbock.

INTRODUCTION

The basic mission of the Goddard Space Flight Center (GSFC), Greenbelt, Maryland, is the exploration of space. This goal is pursued with scientific and application flight projects using the Space Transportation System, expendable vehicles, and balloons.

The Engineering Services Division (ESD), GSFC, maintains a design, fabrication, and integration capability, and conducts environmental test programs to ensure the environmental resistance and functional capability of payloads to operate satisfactorily in space. The three branches that comprise the ESD and provide this capability are:

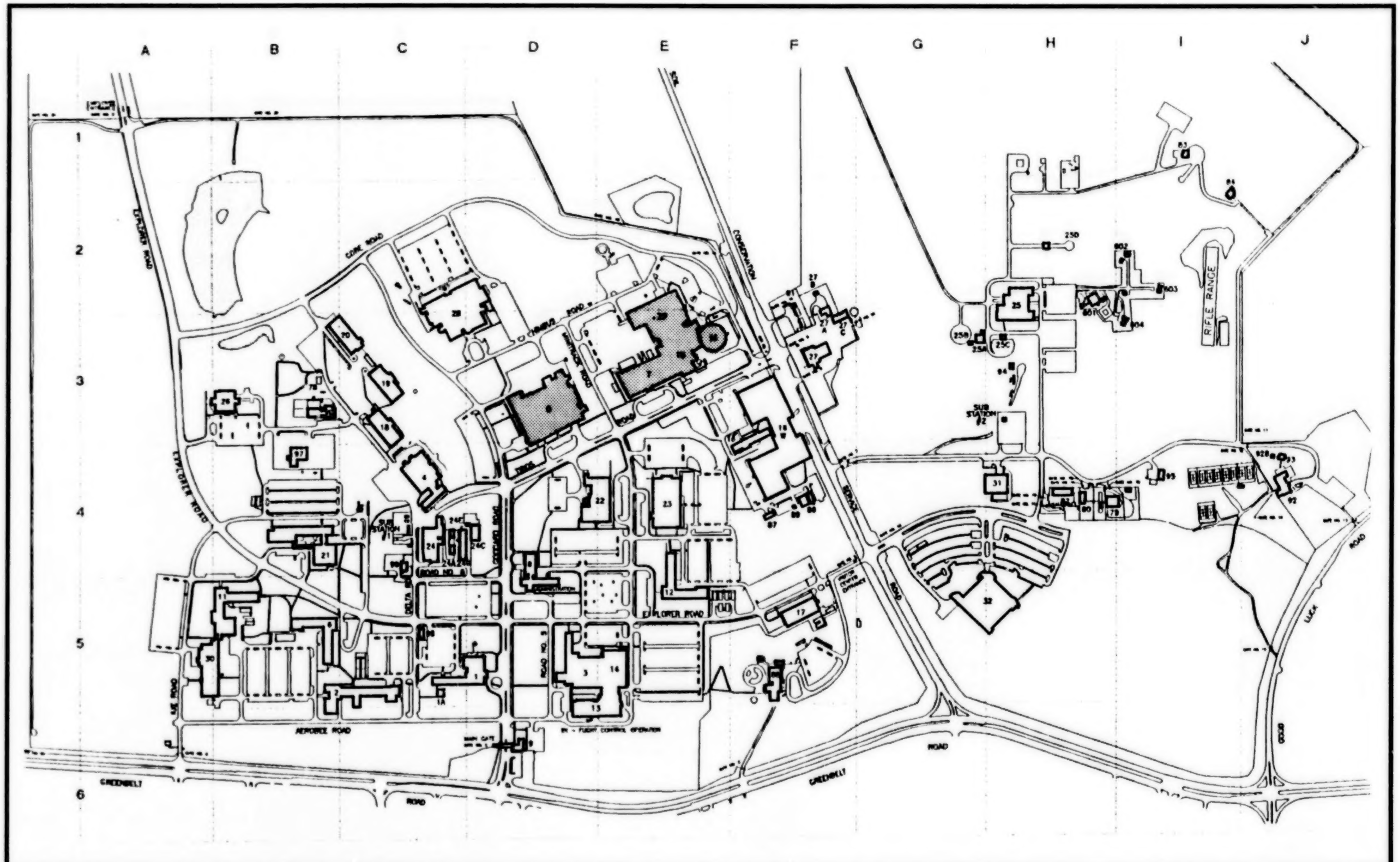
- **Machining Technology Branch (Code 751)**
- **Fabrication Engineering Branch (Code 752)**
- **Environmental Test Engineering and Integration Branch (Code 754)**

This book explains the capabilities and facilities of each of these branches. A layout map of GSFC, showing the building locations of these facilities, appears on the following page. Also included are two User's Guides which list Organizational Contacts and explain how to obtain services from the Engineering Services Division. The User's Guides are contained in the book at the end of the sections shown below:

<u>Title Of User's Guide:</u>	<u>Follows This Section In Book</u>:
ESD Fabrication User's Guide	Fabrication Engineering
ESD Integration And Test User's Guide	Environmental Test Engineering And Integration

Further information on the facilities and capabilities of the Engineering Services Division can be obtained from:

Assistant Chief of Operations
Code 750.9
Goddard Space Flight Center
Greenbelt, Maryland 20771
(301) 286-8747



GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland
Prince George's County
LOCATION MAP

100' 0' 200' 400' 600' 800' 1000'
SCALE IN FEET

Engineering Services Division - Bldg 5
Machining Technology Branch - Bldg 5;
Staff Shops In Bldgs 2, 5W, 10, 22
Fabrication Engineering Branch - Bldg 5
Environmental Test Engineering And Integration Branch - Bldgs 7, 10, 15, 29 And Magnetic Test Facility

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1.0 MACHINING TECHNOLOGY

INTRODUCTION AND CAPABILITY

The Machining Technology Branch maintains a complete manufacturing facility to meet the Center's machining requirements. This includes conventional machining equipment, numerically-controlled (NC) machining centers, and remotely located staff shops.

For conventional manufacturing requirements, milling machines, lathes, and associated support equipment are available for machining metals such as aluminum, alloy steels, and other types of materials, as well as the more exotic aerospace materials and composites. A complete grinding facility is maintained to machine extremely hard materials or to achieve very close tolerances.

Goddard has unique capabilities in the computer-aided manufacturing area. Very large parts can be machined automatically on the very precise, numerically-controlled machining center, which has the capacity of 3.66m (12') of travel in the X axis, 1.83m (6') in the Y axis, and 1.22m (4') in the Z axis. Capable of very precise movement, this machine can position within 0.076mm (0.003") anywhere in the working envelope. Several smaller machining centers and a new turning center produce hardware for GSFC's flight and non-flight projects.

The computer-aided manufacturing effort is supported by an in-house engineering support staff and a network of engineering workstations with state-of-the-art software that is continually updated and enhanced. For example, the APT programming language has been augmented by an APT programming tool called ESDAPT. ESDAPT is an interactive APT programming environment that provides APT language syntax checks, menu-based geometry creation, and graphical tool path display. The APT language was converted from IBM APT source to Fortran F77. ESDAPT was written by staff engineers in the Machining Technology Branch. Both programs are available from COSMIC.

To provide quick reaction support for remotely located experimenters, four staff shops are equipped and staffed with senior technicians. These staff shops have conventional machining capability which allows the engineers and experimenters to have quick modifications performed at or near their work sites.

A fully equipped inspection facility is maintained where work performed can be inspected in progress, prior to its final inspection and approval. This facility can be used by personnel for a quick check of dimensional specifications on parts and sub-assemblies.

The Branch's technical staff advises the engineering and scientific communities at Goddard on the most economical and practical methods of manufacture for spacecraft structures and instruments. In addition, new types of manufacturing technology such as traveling wire electrical discharge machining and coordinate measuring machines are available to meet changing requirements of the Center.

1.1 FABRICATION AND DEVELOPMENT SECTION

The Fabrication and Development Section is composed of conventional and computer NC machines. The section is located on two floors and is equipped to perform precision turning, milling, drilling, and internal/external and surface grinding operations that would be required in any state-of-the-art research and development shop. The section also includes unconventional machining capabilities such as honing, lapping, composite machining, and traveling wire electrical discharge machining.

The section's staff is available for consulting on design, material selection, and fabrication techniques required for prototype development and flight and non-flight hardware. The section performs mechanical assembly of flight/non-flight instruments in a clean room environment. The section designs, draws, and fabricates special purpose fixtures that are required to accomplish tasks and assemblies.

1.2 COMPUTER-AIDED MANUFACTURING

The Computer-Aided Manufacturing (CAM) Section provides support to the GSFC primarily by producing complex prototype, development, and flight components. This task is accomplished by using the Section's computer numerically-controlled (CNC) equipment. This equipment includes CNC wire and ram electrical discharge machines (EDM), five CNC machining centers, a CNC turning/milling center, and a programming system consisting of engineering workstations coupled with in-house enhanced software. The CAM technicians develop programs to control the CNC equipment using programs written in the APT/ESDAPT programming language. These programs are then downloaded to the machines and executed to produce the required components.

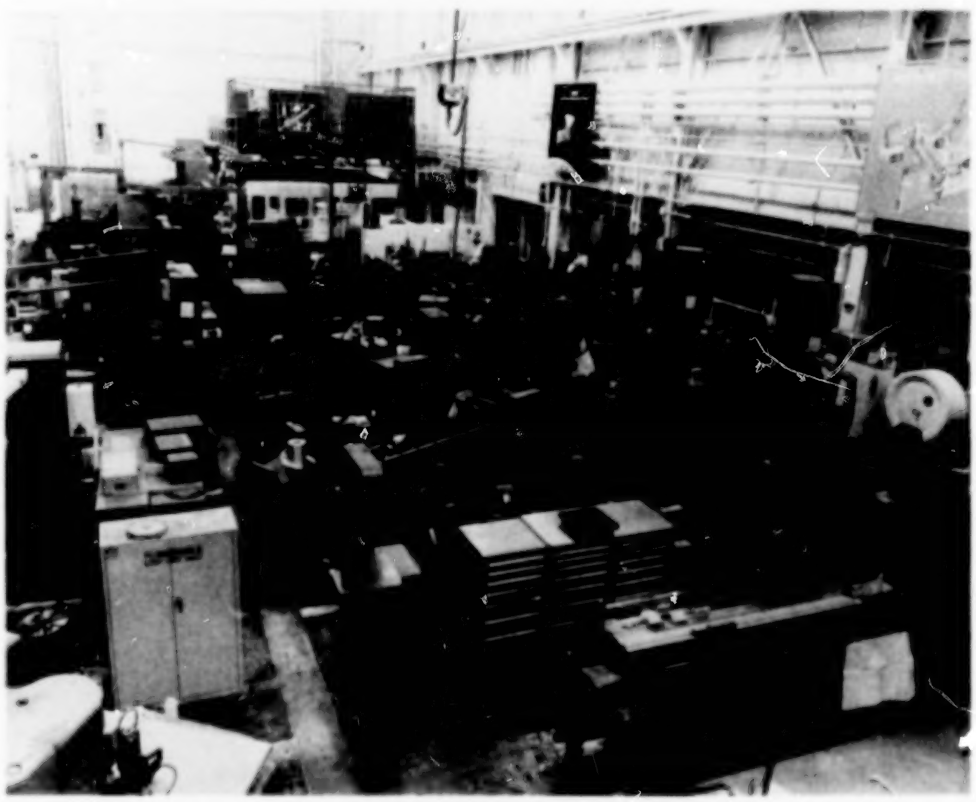
Additionally, the CAM Section provides support in areas such as conventional component production, assembly of development, ETU, and flight units; and consultation services such as design, design for manufacturing, and material selection.

1.3 INSTRUMENT SUPPORT SECTION

The Instrument Support Section is made up of four individual shops located about GSFC. Each shop is staffed by senior technicians who provide technical consultation and developmental services in addition to the fabrication functions. The technicians work directly with the customer to provide rapid response to their requirements. The staff shop locations, personnel, and primary services are listed below:

Bldg. 2, Room C110: Staffed by two journeyman technicians who perform design, development, and fabrication of source detection instruments.
Bldg. 5, Rooms W22 (Assembly Area) and W30: Staffed by one journeyman technician who performs precision assembly and development of small mechanisms.
Bldg. 10, Room B-4: Staffed by two journeyman technicians who support integration and testing activities in Buildings 7, 10, 15, and 29.
Bldg. 22, Room 396: Staffed by two journeyman technicians who support instrument development projects, and precision manufacturing and modification of laser systems.

FABRICATION MACHINE SHOP MEZZANINE LEVEL



FABRICATION MACHINE SHOP MAIN LEVEL

1.4 MACHINING TECHNOLOGY BRANCH CAPABILITIES

Machining Capability	Machine Type	Capacity
Precision turning	Lathe	117cm dia. x 122cm L (46" x 48")
Precision milling	Manual milling machine	61cm L x 91cm W x 122cm H (24" x 36" x 48")
Precision drilling	Lathe, mill, drill press	0.0025cm to 7.6cm dia. (0.001" to 3")
Precision tool grinding	Universal tool grinder	Depends on type of tool
Precision ground diameters	Cylinder grinder	30cm dia. x 86cm L (12" x 34")
Precision surface grinder	Surface grinder	30cm W x 91cm L x 41cm H (12" x 36" x 16")
Precision boring/hole location	Jig borer	91cm W x 122cm L x 142cm H (36" x 48" x 56")
Precision hole/contour grinding	Jig grinder	25cm W x 43cm L x 25cm H (10" x 17" x 10")
Honing (inside diameter)	Honing machine	10cm dia. x 15cm L (4" x 6")
Lapping (flat surface)	Lapping machine	Up to 10cm dia. (4")
Traveling wire cut contouring machine	4-axis CNC traveling wire electrical discharge machine	39.4cm L x 24.1cm W x 39.4cm H (15.5" x 9.5" x 15.5") up to 30° angle
Electrical discharge machining	4-axis CNC RAM type	31cm L x 25cm W x 25cm H (12" x 10" x 10") 200 Kg (440 lb) capacity
Coordinate measuring	Coordinate measuring machine	216cm L x 74cm W x 84cm H (85" x 29" x 33") 771 Kg (1,700 lb) capacity
Precision turning and milling	CNC turning/milling center	41cm dia. x 102cm between centers (16" dia. x 40")
CNC Machining	CNC machining center	X-axis - 3.66m (12') Y-axis - 1.83m (6') Z-axis - 1.22m (4')

1.4.1 DEA GAMMA MOTORIZED COORDINATE MEASURING MACHINE

DESCRIPTION: The DEA Gamma coordinate measuring machine (CMM) is a motorized, vertical bridge-type machine capable of making measurements in three axes. The machine is used to inspect various features of manufactured components to ensure quality and conformance relative to an engineering drawing.

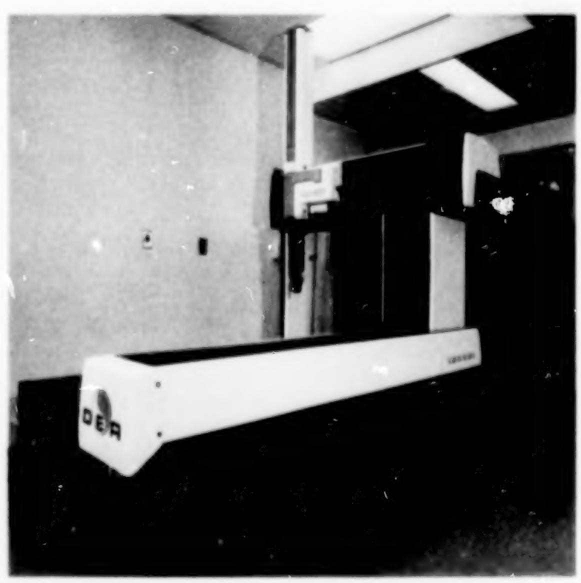
MODE OF OPERATION: Components to be inspected are mounted on the CMM granite work table. A Z-axis-mounted touch probe is then guided, by hand-held joystick control or computer-generated program, to the component to check and record the accuracy of various features. These include planes, diameters, cones, spheres, cylinders, lines, slots, bolt hole patterns, point-to-point measurements, etc. Through the use of an attached PC, software, and printer, actual measurements are taken and the deviations from ideal form are calculated and recorded.

PARAMETERS:

Work piece capacity:	216cm L x 74cm W x 84cm H (85" x 29" x 33")
Work piece weight:	771 Kg (1700 lb)
Travel capacity:	X-axis - 150cm (59"), Y-axis - 66cm (26"), Z-axis - 66cm (26")
Machine performance:	
Repeatability:	0.0020mm (0.00008")
Resolution:	0.0013mm (0.00005")
Volumetric accuracy:	0.0081mm (0.00032")

INTEGRAL INSTRUMENTATION: Renishaw PH-9 electronic probe, Compaq 386/25 IBM-compatible PC, Tutor P measuring software, Citizen 200-GX graphics printer.

DEA GAMMA CONTROL



DEA GAMMA MACHINE

1.4.2 DEA SWIFT COORDINATE MEASURING MACHINE

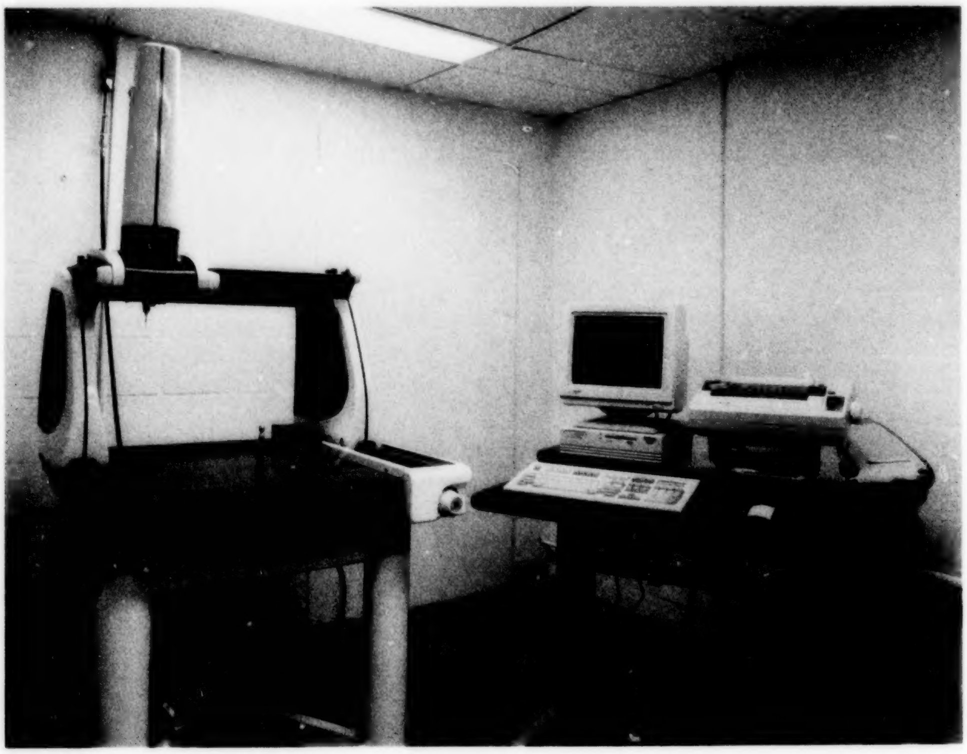
DESCRIPTION: The DEA swift coordinate measuring machine (CMM) is a manually operated, vertical bridge-type machine capable of making measurements in three axes. The machine is used to inspect various features of manufactured components to ensure quality and conformance relative to an engineering drawing.

MODE OF OPERATION: Components to be inspected are mounted on the CMM granite work table. A Z-axis-mounted electronic touch probe is then manually guided to the component to check and record the accuracy of features such as planes, diameters, cones, spheres, cylinders, lines, slots, bolt hole patterns, point-to-point measurements, etc. Through the use of an attached PC, software, and printer, actual measurements are taken and the deviations from ideal form are calculated and recorded.

PARAMETERS:

Work piece capacity:	46cm L x 61cm W x 38cm H (18" x 24" x 15")
Work piece weight:	68 Kg (150 lb)
Travel capacity:	X-axis - 36cm (14"), Y-axis - 41cm (16"), Z-axis - 30cm (12")
Machine performance:	
Linear Accuracy:	0.0064mm (0.00025")
Repeatability:	0.0041mm (0.00016")
Resolution:	0.0010mm (0.00004")

INTEGRAL INSTRUMENTATION: Electronic touch probe, Compaq 386/25 IBM- compatible PC, Tutor P measuring software, Citizen 200-GX graphics printer, and 3-point machine stand.



1.4.3 TRAVELING WIRE ELECTRICAL DISCHARGE MACHINE

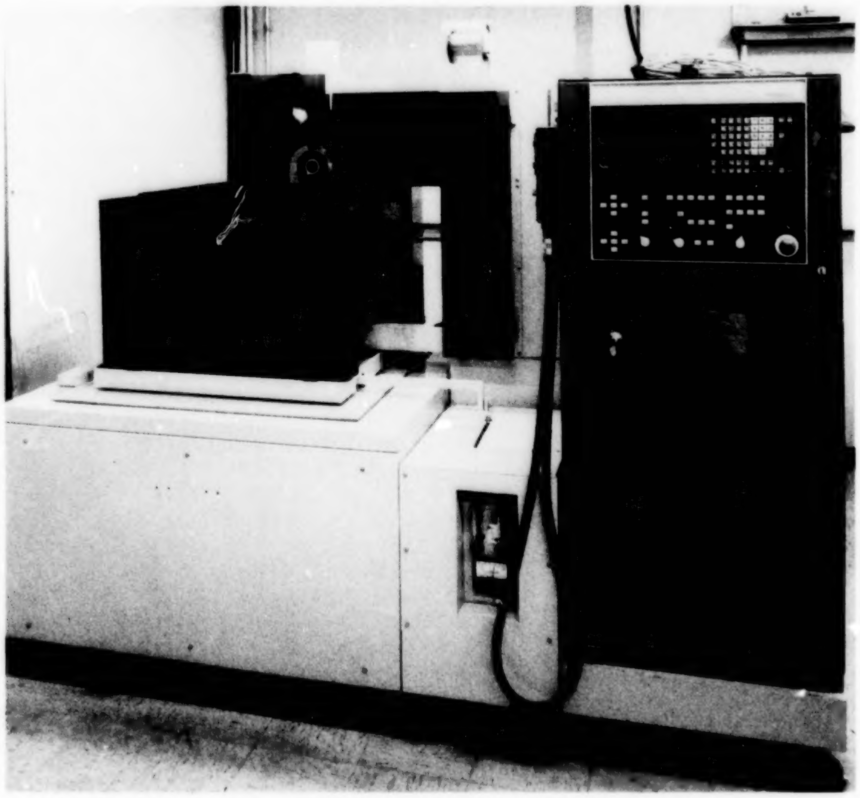
DESCRIPTION: This is a CNC machine which uses an electrically charged moving wire to produce complex shapes in conductive materials (metals). Components can be machined from extremely hard materials in minute detail or complex shapes too difficult for conventional machining.

MODE OF OPERATION: A CNC unit is used to move a precisely-tensioned wire in a prescribed path. A voltage is applied to this continuously moving wire while the work piece and wire are flooded with deionized water. As the wire approaches the work piece, an electrical discharge occurs, vaporizing a small amount of metal. The process continues automatically until the wire moves through the programmed path. Axes X, Y, U and V are controlled simultaneously. Fanuc servo motors, coupled directly to precision ball screws and compensated for error, position the wire for cutting.

PARAMETERS:

Wire size:	0.051mm - 0.305mm diameter (0.002" - 0.012")
Work piece capacity:	33cm W x 43cm L x 27cm H (13" x 17" x 10.6")
Work piece weight:	159 Kg (350 lb)
Resolution:	0.00102mm (0.00004")
Tapered surfaces:	Up to ± 20° and 3.8cm thickness (1.5")

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk drive unit integral with the CNC unit.



1.4.4 ROBOFORM 20 ELECTRICAL DISCHARGE MACHINE

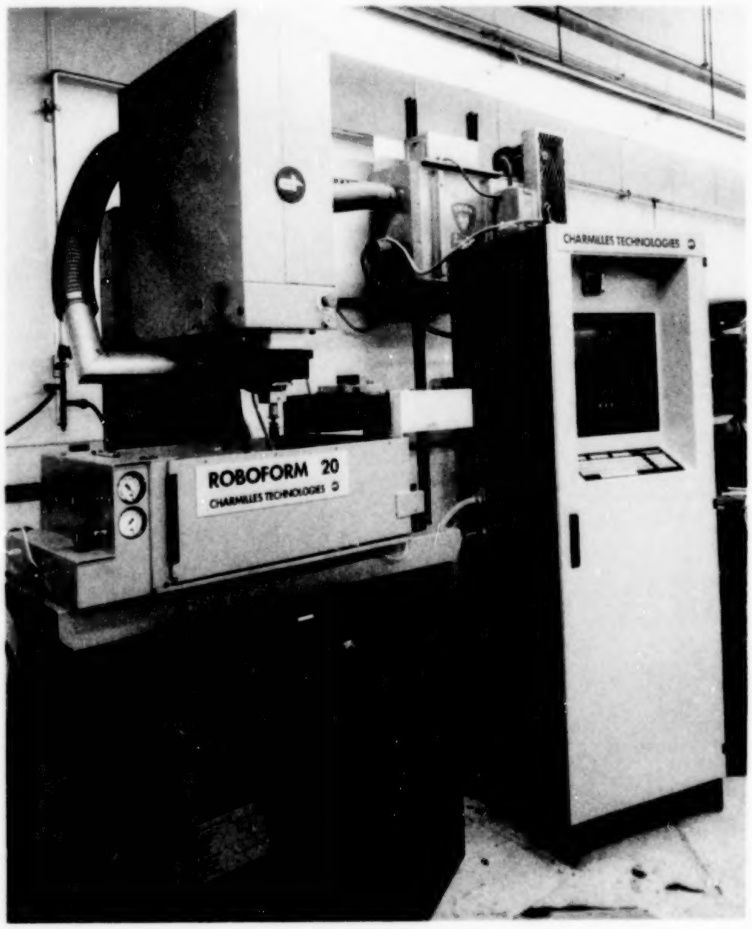
DESCRIPTION: The Charmilles Roboform 20 CNC ram electrical discharge machine (EDM) is a 4-axis precision machining system that is capable of cutting electrically conductive materials, including hardened metals, to precise tolerances.

MODE OF OPERATION: A CNC unit is used to guide an electrode along a programmed path. A voltage is applied to this electrode and, as it approaches the work piece, an electrical discharge occurs, vaporizing a small amount of metal. The process continues automatically, directed by CNC control. Machine movements occur in the X, Y, Z, and C (electrode indexing and rotation) axes. Linear, angular, orbital, conical, and helical moves can be performed by this machine.

PARAMETERS:

Travel in X, Y, Z:	X-axis - 30.0cm (11.8"), Y-axis - 24.9cm (9.8"), Z-axis - 24.9cm (9.8")
Travel in C axis:	360 degrees
Work piece size:	up to 51cm L x 38cm W x 17.8 cm H (20" x 15" x 7")
Work piece weight:	up to 200 Kg (440 lb)

INTEGRAL INSTRUMENTATION: Charmilles CNC control unit; Remcor dielectric chiller; 4-position automatic electrode changer. NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit attached to the Charmilles CNC control unit.



1.4.5 ROBOFIL 300 ELECTRICAL DISCHARGE MACHINE

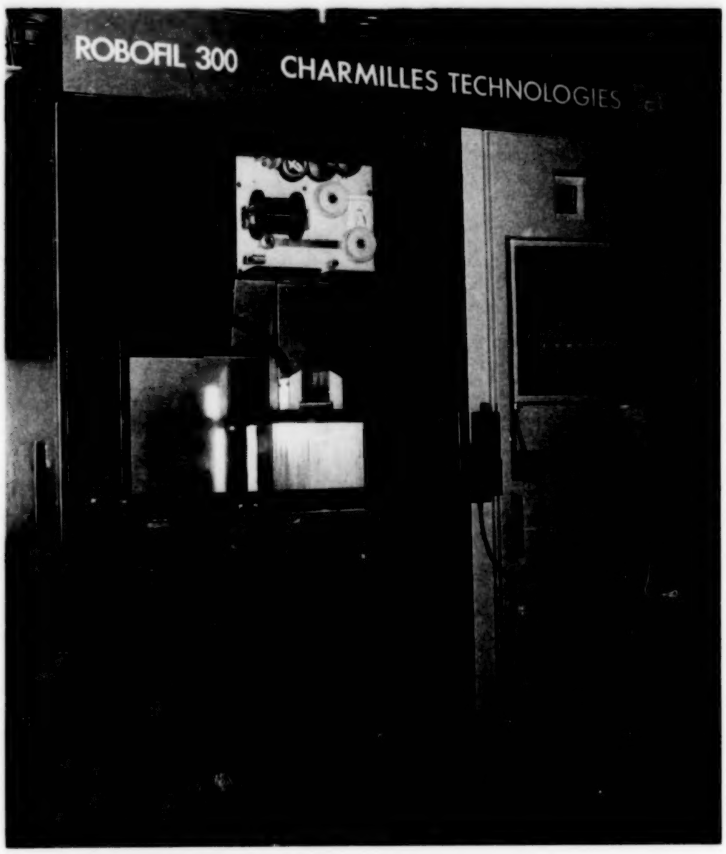
DESCRIPTION: The Charmilles Robofil 300 wire electrical discharge machine is a 5-axis (4 contouring axes, X, Y, U, V and one positioning axis, Z) that is capable of cutting electrically conductive materials to precise tolerances using a continuously moving wire as an electrode.

MODE OF OPERATION: A CNC unit is used to move a precisely-tensioned wire in a prescribed path. A voltage is applied to the continuously moving wire while the work piece and wire are flooded with deionized water. As the wire approaches the work piece, an electrical discharge occurs, vaporizing a small amount of metal. The process continues automatically until the wire moves through the programmed path.

PARAMETERS:

Wire size:	0.010cm - 0.030cm diameter (0.004" - 0.012")
Work piece size:	39cm L x 24cm W x 39cm H (15.5" x 9.5" x 15.5")
Work piece weight:	499 Kg (1100 lb)

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a disk drive unit integral with the Charmilles CNC unit.



1.4.6 ROBOFIL 600 ELECTRICAL DISCHARGE MACHINE

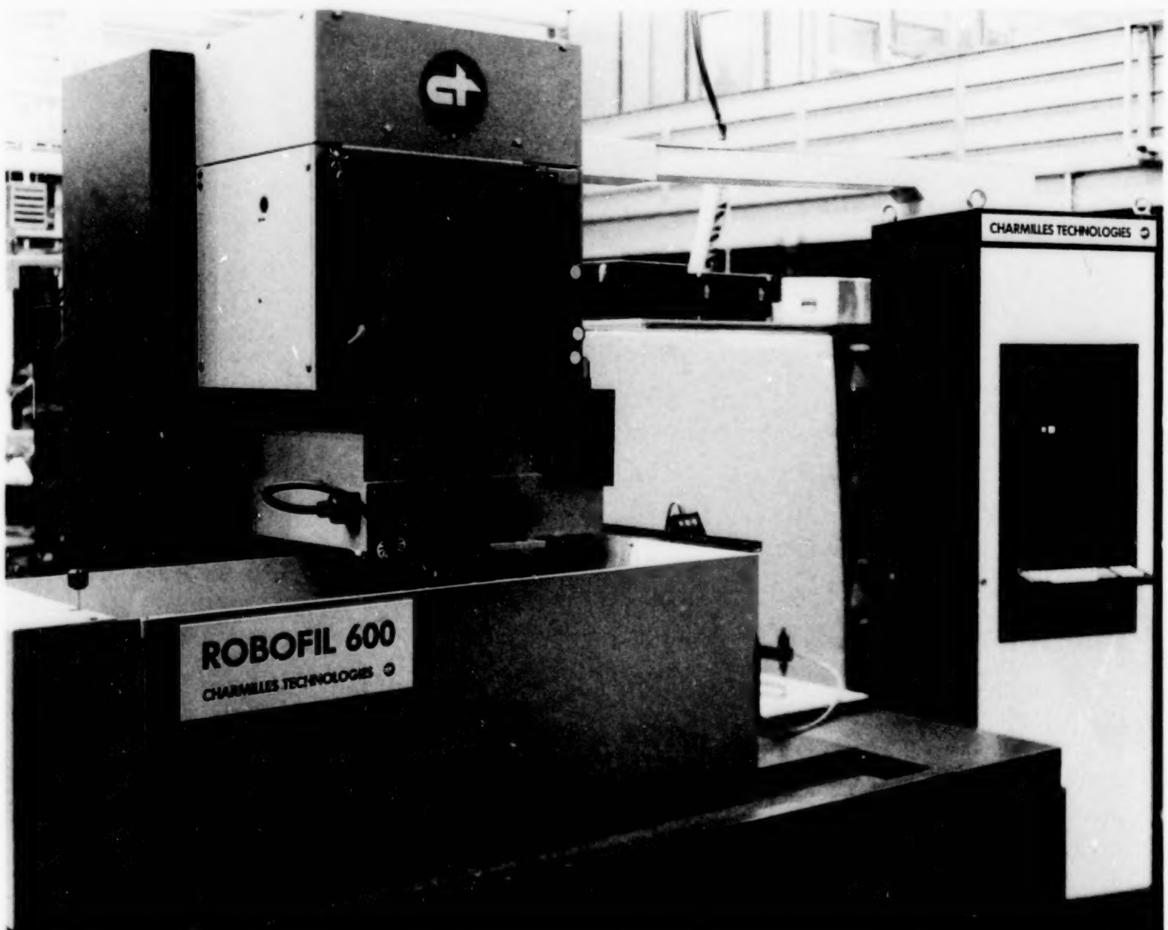
DESCRIPTION: The Charmilles Robofil 600 wire electrical discharge machine is a 5-axis machining system that is capable of cutting electrically conductive materials, including hardened metals, to precise tolerances.

MODE OF OPERATION: A CNC unit is used to move a precisely-tensioned wire along a programmed path. A voltage is applied to the continuously moving wire while the work piece and wire are submerged in deionized water. As the wire approaches the work piece, an electrical discharge occurs, vaporizing a small amount of metal. The process continues automatically, directed by CNC control. Four of the five axes (X, Y, U, V) can be operated simultaneously, allowing for taper cutting and complex shapes to be machined.

PARAMETERS:

Travel capacity:	X-axis - 63.0cm (24.80"), Y-axis - 40.0cm (15.74"), Z-axis - 26.0cm (10.25")
Taper cutting:	Up to 30°
Work piece size:	119cm L x 69cm W x 25cm H (47" x 27" x 10")
Work piece weight:	499 Kg (1100 lb)

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a disk drive unit integral with the Charmilles CNC control unit.



1.4.7 DECKEL FP4-NC UNIVERSAL MILLING MACHINE

DESCRIPTION: The three Deckel FP4-NC milling machines are capable of performing precision machining operations in either a horizontal or vertical configuration.

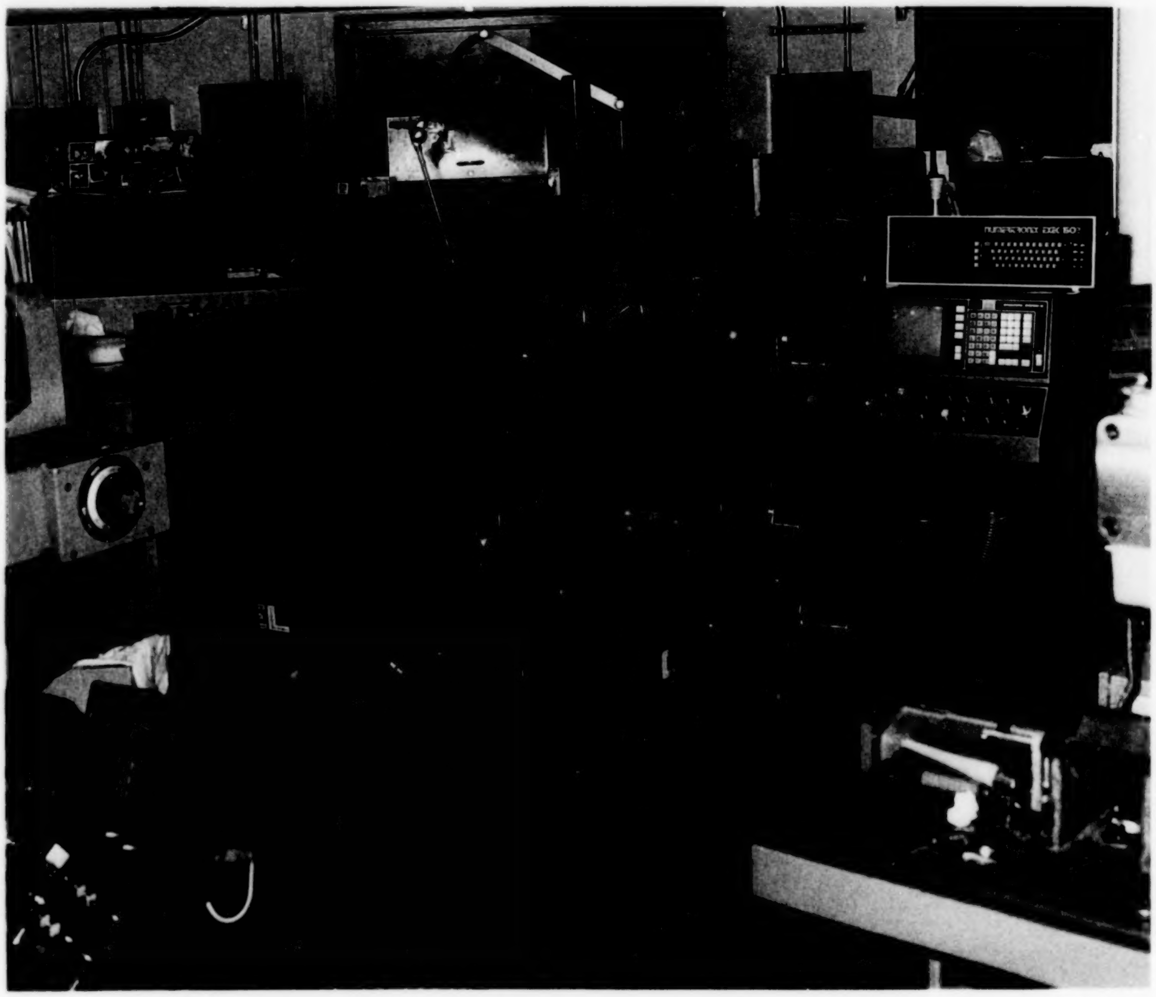
MODE OF OPERATION: These machines can be used for milling in a conventional mode, or as fully automated machines that are programmed either at the local control console or, remotely, using an APT program.

PARAMETERS:

Travel capability:

X-axis - 55.25cm (21.750"), Y-axis - 43.82cm (17.250"), Z-axis - 35.82cm (14.100")

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the Bendix Dynapath-10 CNC control unit.



1.4.8 JIG BORER

DESCRIPTION: This precise positioning, boring, drilling and milling machine uses optical scales to ensure accuracy. It supplements smaller numerically-controlled and manual milling and drilling machines.

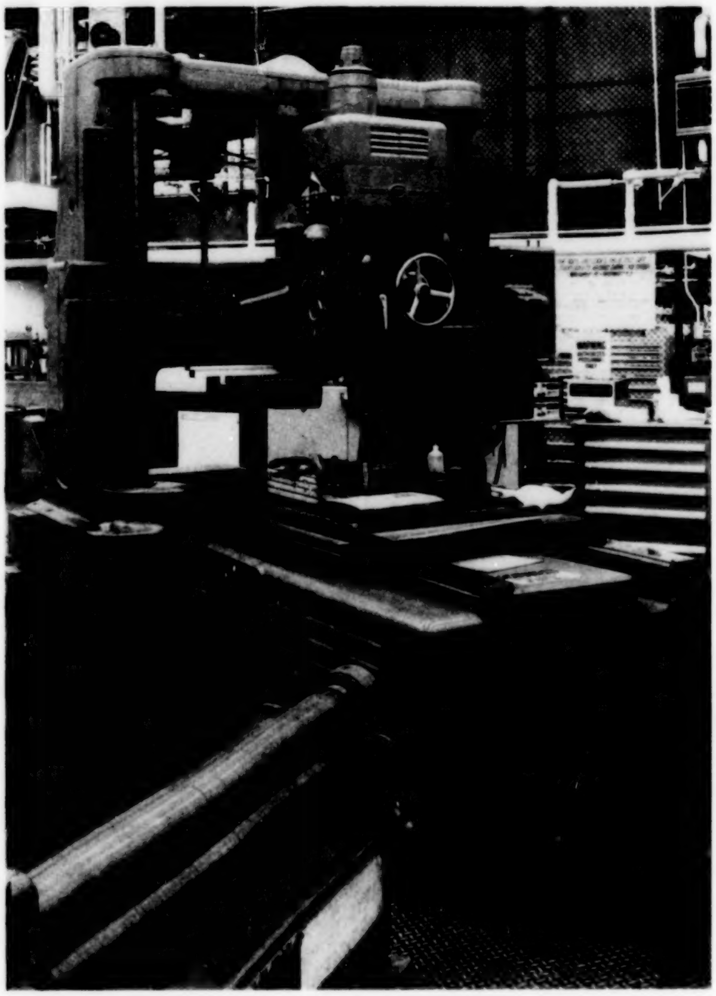
MODE OF OPERATION: This machine is operated manually with power feeds in all axes.

PARAMETERS:

X-axis travel:	137cm (54")
Y-axis travel	102cm (40")
Z-axis travel:	30cm (12")
Maximum capacity:	91cm W x 122cm L x 142cm H up to 907 Kg (36" x 48" x 56" up to 2,000 lb)

INTEGRAL INSTRUMENTATION: This machine is equipped with optical and digital readouts for precise measuring and positioning.

ADDITIONAL NOTES: Angular and rotary motions up to 91cm (36") diameter can be achieved with accessories.



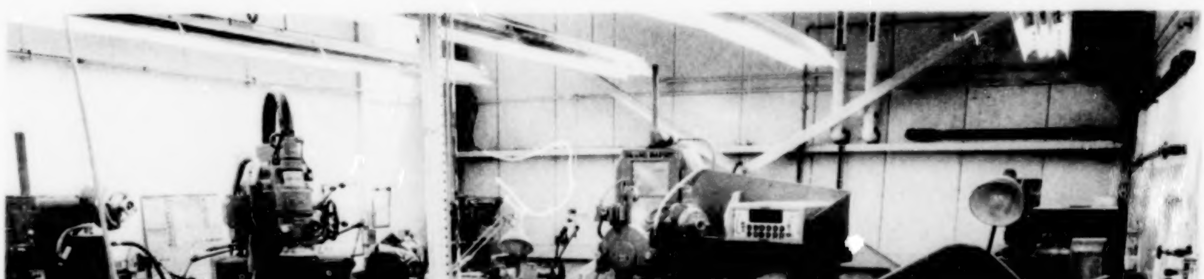
1.4.9 PRECISION GRINDING FACILITY

DESCRIPTION: This facility includes basic precision grinding equipment such as cylindrical, surface, tool, and center grinders, and a flat lapping machine.

MODE OF OPERATION: Extremely hard metals and ceramics are readily shaped to precise tolerances using aluminum oxide, silicon carbide, cubic boron nitride, or diamond grinding wheels. Equipment in this facility is basically manual control with automatic feeds.

PARAMETERS:

Diameter:	Up to 25cm (10")
Length:	Up to 71cm (28")
Flat surfaces:	30cm L x 91cm W x 41cm H (12" x 36" x 16")
Flat lapping:	11cm diameter maximum (4.25")



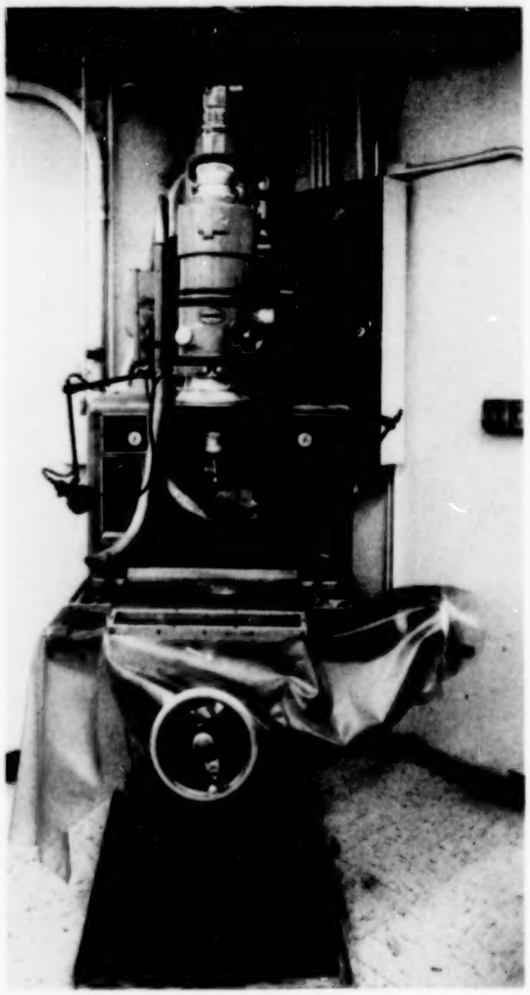
1.4.10 JIG GRINDER

DESCRIPTION: This precision grinding facility is equipped with a precision hole grinding machine used to grind hard metals or ceramic work pieces. It uses aluminum oxide, diamond, or cubic boron nitride grinding wheels to grind holes in hardened steels to precise location and tolerances. It supplements other hole producing machinery.

MODE OF OPERATION: The machine's operation centers around a high-speed air turbine with auxiliary electric rotating head with reciprocating quill.

PARAMETERS:

Work piece size:	Up to 25cm W x 43cm H x 25cm L (10" x 17" x 10")
Hole grinding range:	0.051cm to 15cm diameter (0.020" to 6")
Speed:	60,000 RPM maximum
Tapered holes:	Up to 6° included angle



1.4.11 BURGMASTER VTC-150 3-AXIS CNC MACHINING CENTER

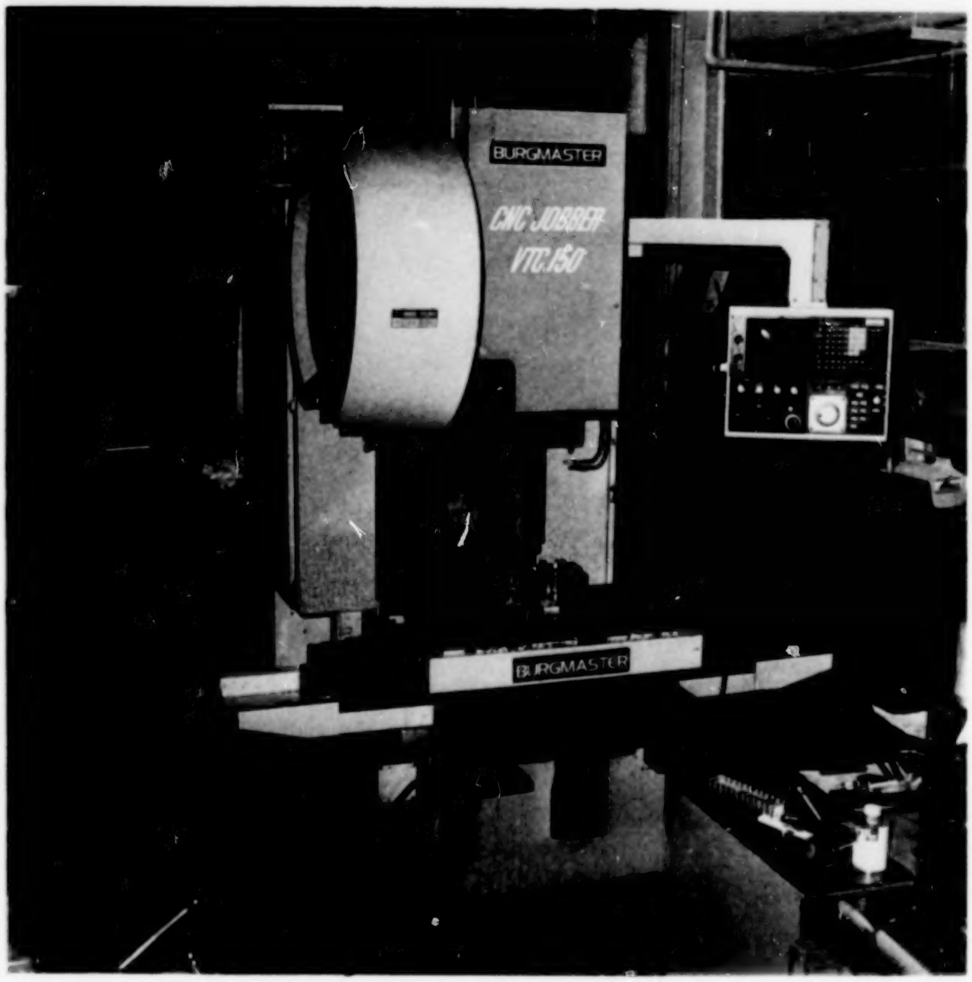
DESCRIPTION: The Burgmaster VTC-150 3-axis machining center is a precision vertical milling machine. It has the capability to perform precision boring, milling, drilling and tapping operations.

MODE OF OPERATION: The machining center is used for fully automated milling in up to 3 axes of simultaneous motion.

PARAMETERS:

Travel capability: X-axis - 76cm (30"), Y-axis - 38cm (15"), Z-axis - 36cm (14")

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the General Numerics CNC control unit.



1.4.12 CINCINNATI 10H-1500 3-AXIS MACHINING CENTER

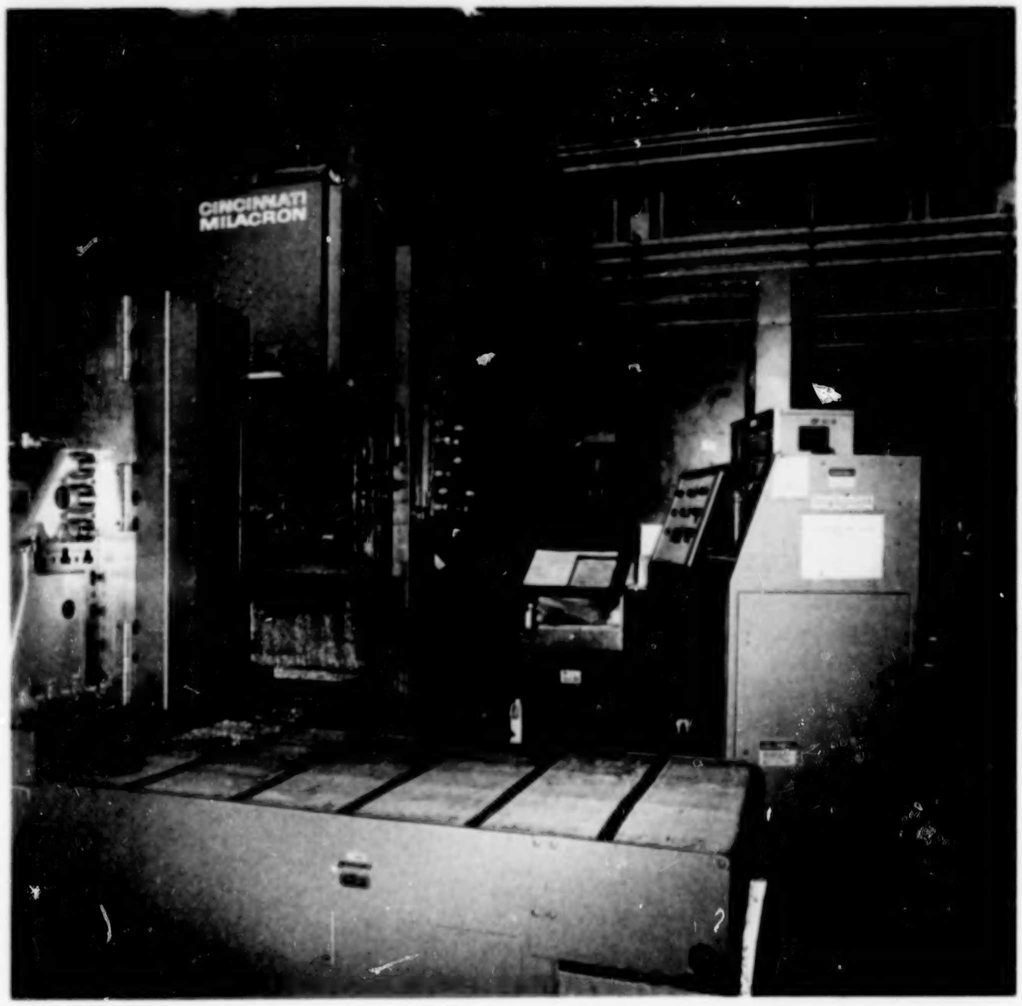
DESCRIPTION: The Cincinnati 10H-1500 machining center is a precision horizontal milling machine. It has the capability to perform precision boring, milling, drilling and tapping operations.

MODE OF OPERATION: The machining center is used for fully automated milling in up to 3 axes of simultaneous motion. A CNC controlled indexing rotary table is also available.

PARAMETERS:

Travel capability: X-axis - 152cm (60"), Y-axis - 102cm (40"), Z-axis - 61cm (24")

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the Acramatic CNC control unit.



1.4.13 CINCINNATI 10V-1250 3-AXIS CNC MACHINING CENTER

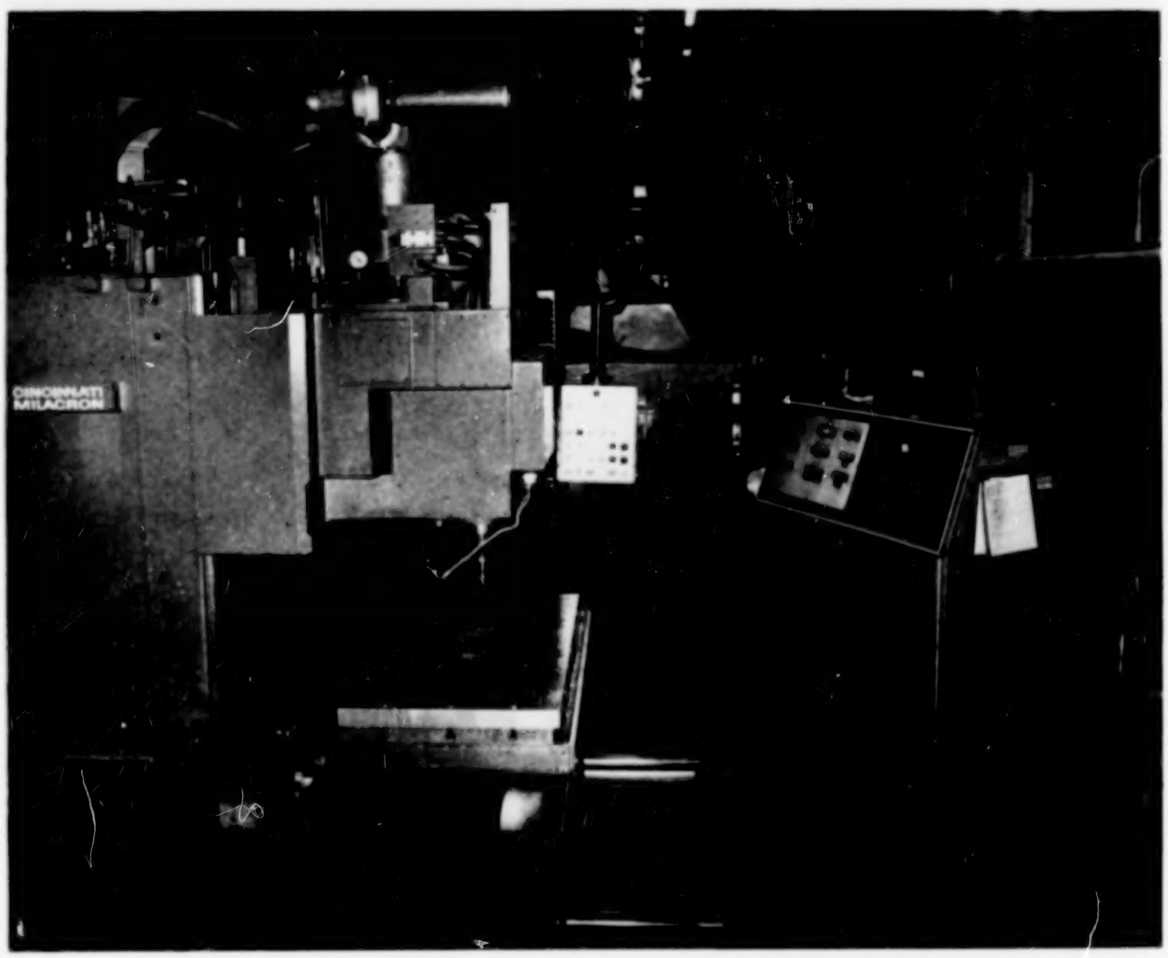
DESCRIPTION: The Cincinnati 10V-1250 CNC machining center is a precision vertical milling machine. It has the capability to perform precision boring, milling, drilling and tapping operations.

MODE OF OPERATION: The machining center is used for fully automated milling in up to 3 axes of simultaneous motion.

PARAMETERS:

Travel capability: X-axis - 127cm (50"), Y-axis - 66cm (26"), Z-axis - 59.06cm (23.250")

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the Acramatic CNC control unit.



1.4.14 DE VLIEG 4-AXIS CNC MACHINING CENTER

DESCRIPTION: The De Vlieg machining center is a precision horizontal boring and milling machine used for production of large shuttle-sized mechanical components and instruments. It has complete boring, milling, drilling and tapping capabilities with a high degree of accuracy and precision. A four-axis numerical control system provides linear and circular interpolation and three-axis contouring. Basic slide arrangement is a horizontal travel table-saddle (X-axis) mounted on the machine bed, a vertical travel spindlehead (Y-axis) mounted on the column, a horizontal table movement (W-axis) perpendicular to the X-axis and parallel to the W-axis mounted in the spindlehead.

MODE OF OPERATION: The machining center is used for fully automated contour milling in three and four axes of simultaneous motion.

PARAMETERS:

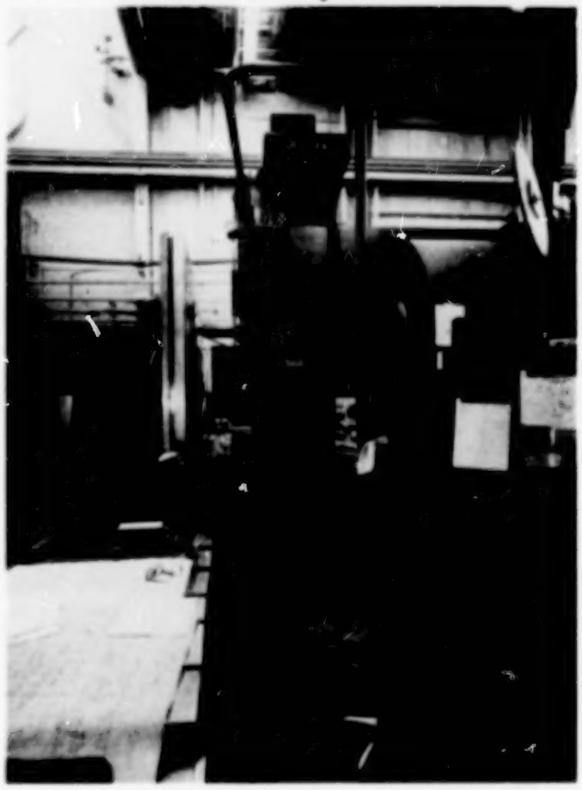
Travel (X,Y,Z):	X-axis - 3.66m (12'), Y-axis - 1.83m (6'), Z-axis - 61cm (24")
Travel (W):	W-axis - 61cm (24")
No load accuracy:	Within 0.076mm over 3.66m (0.003" over 12')
Repeatability:	Within 0.00381mm (0.00015")

18.6 Kw (25 HP) spindle and DC electric servo table drives

INTEGRAL INSTRUMENTATION:

Allen Bradley TAPAC CNC-7320 control unit, JMC automatic tool changer, and contour boring head

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the Allen Bradley 7320 CNC control unit.



1.4.15 DYNA 2800 CNC MACHINING CENTER

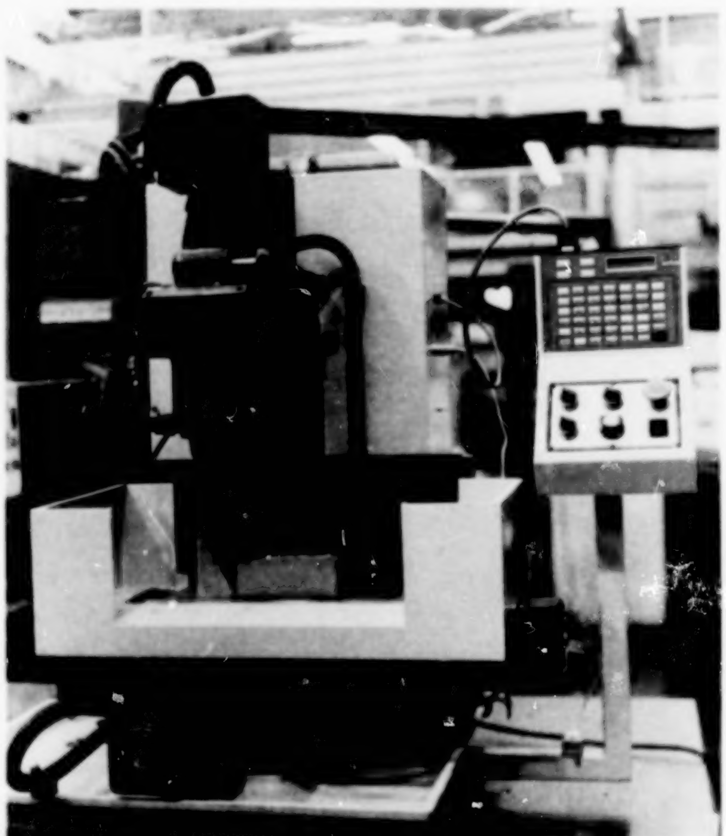
DESCRIPTION: The Dyna 2800 CNC machining center is a bed type 3-axis CNC milling machine. It is a "tabletop" machine designed to perform drilling, milling, and boring operations used to produce small components.

MODE OF OPERATION: Machining is achieved by mounting the work piece to the machine table. Spindle mounted rotary tooling is directed by a user-programmable CNC control unit to machine the work piece to the desired shape. A CNC rotary table may be mounted to the machine table for production of more complex items.

PARAMETERS:

Travel capability:	X-axis - 20cm (8"), Y-axis - 15cm (6"), Z-axis - 18cm (7")
Spindle speed:	0-8,000 RPM

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Greco CNC station disk drive unit connected directly to the DYNA CNC control unit.



1.4.16 WASINO LJ-10MC CNC TURNING/MILLING CENTER

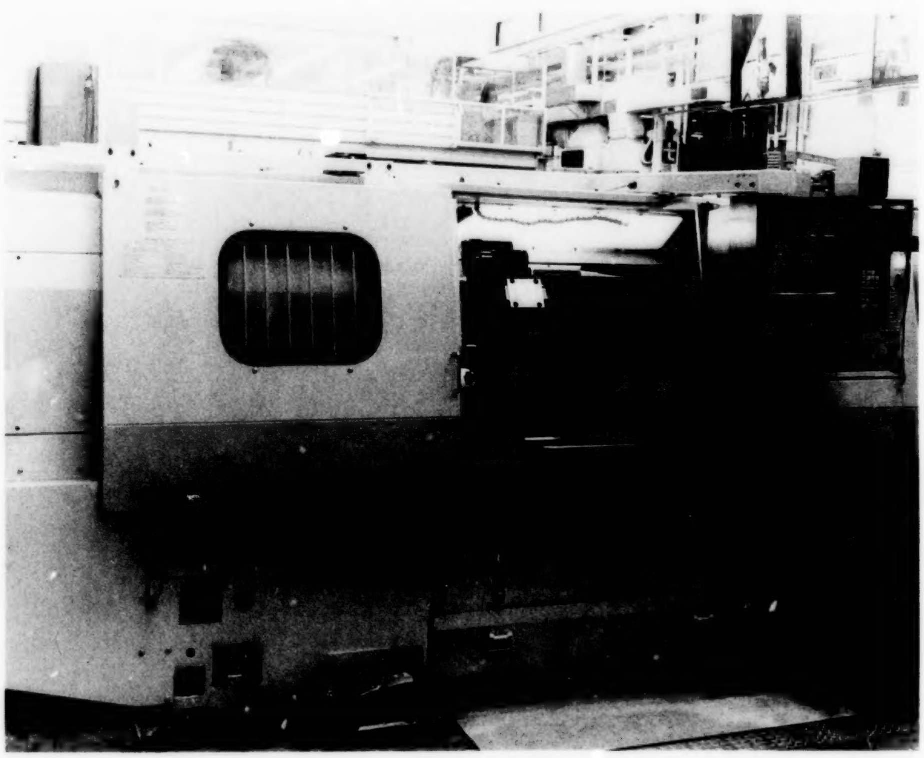
DESCRIPTION: The Wasino LJ-10MC CNC turning/milling center is a precision machining system. It is capable of producing complex work pieces that require turning or milling in cross and axial directions, off center drilling/tapping, spiral cutting, thread cutting, and cam contouring.

MODE OF OPERATION: Materials are machined either by turning or milling. In the turning mode, the chuck-mounted work piece rotates and is machined by stationary turret-mounted tooling. In the milling mode, the chuck-mounted work piece is held stationary and is machined by turret-mounted rotary-driven tooling. In this mode, the chuck may be indexed or continuously driven to be used as an indexing or contouring rotary table.

PARAMETERS:

Capacity between centers:	102cm (40")
Swing over bed:	41.0cm (16.12")
Travel capacity:	X-axis - 24.5cm (9.625"), Z-axis - 102.5cm (40.375")
C-axis minimum increment:	0.001°
Spindle speed:	
Low range:	10-1060 RPM infinitely variable
High range:	35-3500 RPM infinitely variable

DATA ACQUISITION: NC part program data is transferred via an 8.9cm (3.5") floppy disk to a Fanuc disk drive unit attached directly to the Fanuc 15-TF CNC control unit.



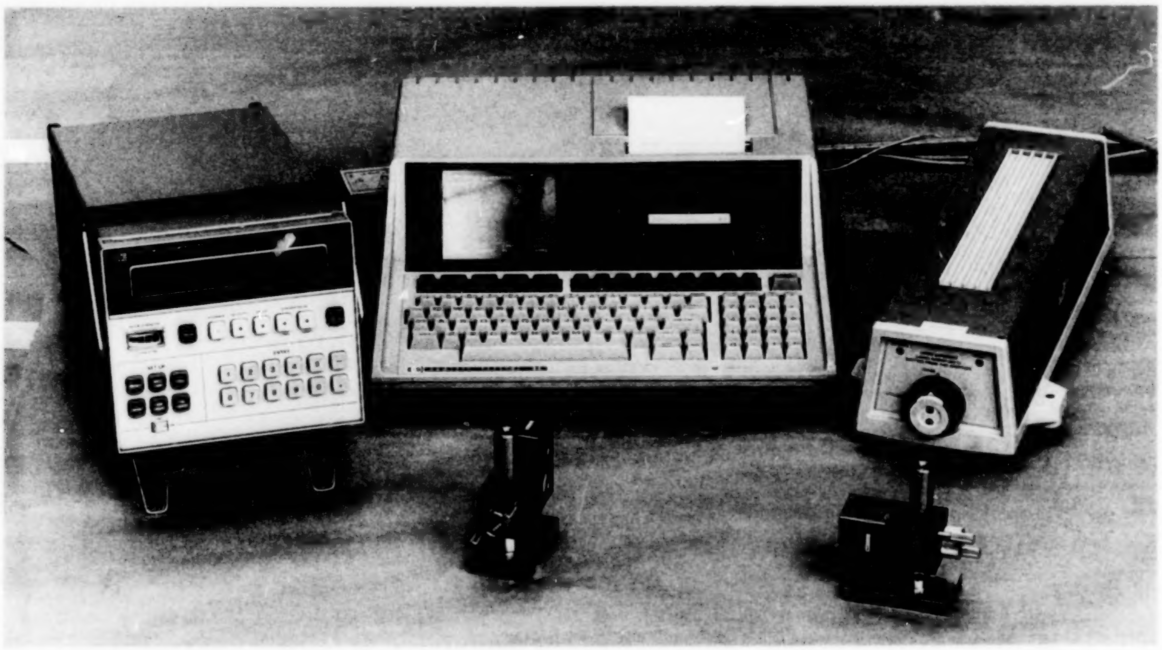
1.4.17 LASER MEASUREMENT SYSTEM

DESCRIPTION: The Hewlett-Packard Model 5528A laser measurement system is a portable, lightweight, dimensional measurement system. It consists of the 5518A laser head, 5508A measurement display, HP-85 personal computer, HP-7470 graphics plotter, and various optical tooling devices.

MODE OF OPERATION: The system is capable of making single-axis measurements by laser interferometry including distance, velocity, angular, flatness, straightness, and squareness. It is used principally to calibrate the axes of machine tools and flatness of surface tables.

PARAMETERS:

Linear distance measurement resolution:	0.01 micron (3.94×10^{-7} inch)
Angle measurement accuracy:	± 0.05 arc-sec
Straightness measurement accuracy:	0.04 microns/meter (4.80×10^{-7} inch/foot)



1.5 REMOTELY LOCATED MACHINERY/CAPABILITIES (SI UNITS)

Operation	Machine Type	Capability (SI Units)
Building 2		
Milling	Deckel FP4M Bridgeport	78.7cm x 45.7cm table, 39.4cm x 50.8cm x 39.4cm travel 121.9cm x 22.9cm table, 71.1cm x 30.5cm x 35.6cm travel
Turning	Monarch lathe Hardinge Toolroom lathe	25.4cm swing x 91.4cm bed, 66.0cm between centers 15.2cm swing x 91.4cm bed, 40.6cm between centers
Drilling	Clausing drill press	#2 Morse taper spindle, 45.7cm square table, 76.2cm vertical capacity
Building 10		
Milling	Cincinnati Deckel FP4M	132.1cm x 30.5cm table, 61.0cm x 22.9cm x 38.1cm travel 78.7cm x 45.7cm table, 39.4cm x 50.8cm x 39.4cm travel
Turning	Monarch Monarch	25.4cm swing x 76.2cm bed, 50.8cm between centers 40.6cm swing x 198.1cm bed, 152.4cm between centers
Drilling	Clausing drill press	#2 Morse taper, 50.8cm square table, 76.2cm vertical capacity
Building 22		
Milling	Deckel FP4M (2 each) Bridgeport	78.7cm x 45.7cm table, 39.4cm x 50.8cm x 39.4cm travel 106.7cm x 22.9cm table, 55.9cm x 30.5cm x 35.6cm travel
Turning	Monarch Hardinge LeBlond	25.4cm swing x 91.4cm bed, 66.0cm between centers 15.2 cm swing x 91.4cm bed, 40.6cm between centers, digital readout ± 0.0127mm accuracy, English/Metric 35.6cm swing x 127.0 cm bed, 61.0cm between centers
Drilling	Clausing drill press Precision drill press	#2 Morse taper, 45.7cm square table, 76.2cm vertical capacity
Building 5W		
Milling	Bridgeport	106.7cm x 22.9cm table, 55.9cm x 30.5cm x 35.6cm travel
Turning	Hardinge Toolroom	15.2cm swing x 91.4cm bed, 40.6cm between centers

All staff shops have limited sawing, sanding, grinding, and drilling capabilities. The Hardinge lathe in the Building 5 Staff Shop can cut metric threads. All shops have digital readouts on the lathes and mills, with the ability to read travels in Metric or English measure.

1.5 REMOTELY LOCATED MACHINERY/CAPABILITIES (ENGLISH UNITS)

Operation	Machine Type	Capability (English Units)
		Building 2
Milling	Deckel FP4M Bridgeport	31" x 18" table, 15.5" x 20" x 15.5" travel 48" x 9" table, 28" x 12" x 14" travel
Turning	Monarch lathe Hardinge Toolroom lathe	10" swing x 36" bed, 26" between centers 6" swing x 36" bed, 16" between centers
Drilling	Clausing drill press	#2 Morse taper spindle, 18" square table, 30" vertical capacity
		Building 10
Milling	Cincinnati Deckel FP4M	52" x 12" table, 24" x 9" x 15" travel 31" x 18" table, 15.5" x 20" x 15.5" travel
Turning	Monarch Monarch	10" swing x 30" bed, 20" between centers 16" swing x 78" bed, 60" between centers
Drilling	Clausing drill press	#2 Morse taper, 20" square table, 30" vertical capacity
		Building 22
Milling	Deckel FP4M (2 each) Bridgeport	31" x 18" table, 15.5" x 20" x 15.5" travel 42" x 9" table, 22" x 12" x 14" travel
Turning	Monarch Hardinge LeBlond	10" swing x 36" bed, 26" between centers 6" swing x 36" bed, 16" between centers, digital readout ± 0.0005" accuracy, English/Metric 14" swing x 50" bed, 24" between centers
Drilling	Clausing drill press Precision drill press	#2 Morse taper, 18" square table, 30" vertical capacity
		Building 5W
Milling	Bridgeport	42" x 9" table, 22" x 12" x 14" travel
Turning	Hardinge Toolroom	6" swing x 36" bed, 16" between centers

All staff shops have limited sawing, sanding, grinding, and drilling capabilities. The Hardinge lathe in the Building 5 Staff Shop can cut metric threads. All shops have digital readouts on the lathes and mills, with the ability to read travels in Metric or English measure.

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2.0 FABRICATION ENGINEERING

INTRODUCTION

The Fabrication Engineering Branch is comprised of three sections: Fabrication Management Section, Spacecraft Assembly Section, and Plating And Plastics Section. The Branch's primary function is to evaluate existing fabrication methods, processes, and equipment, and to develop new processes in the fabrication of precision sheet metal structures, welding, plastics, plating, and advanced composite structures.

2.1 FABRICATION MANAGEMENT

The Fabrication Management Section reviews incoming designs for producibility, and decides whether work should be performed commercially or on-site. This section plans, estimates, schedules, coordinates, and expedites all fabrication work, introducing and applying advanced technology in the manufacturing field. The commercially performed services are provided by a series of contracts with approximately 50 small business companies in the Baltimore/Washington area. These services include the areas of machining, sheet metal, heat treating, welding, plastics, woodworking, model making, engraving, painting, electroplating, and assembly. The size and capabilities of these companies vary from small (one and two man) shops to companies over 90 employees. Some shops have only small machines, while others have machines large enough to handle shuttle-sized components.

2.2 SPACECRAFT ASSEMBLY

The Spacecraft Assembly Section is responsible for constructing, assembling, and modifying spacecraft hardware and systems for fabricating experimental components, laboratory instruments and ground support equipment. These spacecraft components generally fly on Shuttle, Delta rocket, and balloon flight missions. These efforts are accomplished by skilled aerospace technical personnel using state-of-the-art metal forming and alignment equipment. Our main charter is the assembly of spacecraft hardware. In addition to assembly and fabrication, our technicians are available for consultation for future assembly techniques and equipment parameters that can be included in design and fabrication planning by the various project engineers. In line with this, we provide Engineering Tutorials on subjects such as: fastener types and applications, metal bending, etc. Our section has two videos that may be viewed at Goddard's Information Technology Center (ITC) entitled Design Considerations For Welding and Design Considerations For Metal Forming And Punching.

The Spacecraft Assembly Section also includes our welding laboratory. The welding lab is responsible for fabricating, modifying, repairing, and testing cryogenic and hard-vacuum components and systems. The Section provides assembly services to projects for the experimental construction, assembly, and modification of prototype spacecraft, including consultant work for weld design throughout the Center and for various project support.

2.2.1 SPACECRAFT ASSEMBLY FACILITIES
2.2.1.1 SPACECRAFT ASSEMBLY AREA

DESCRIPTION: The spacecraft assembly area is a high bay facility in Building 5 adjacent to the manufacturing facilities. The area is used for assembling shuttle-sized spacecraft structures, and the assembly tables are adaptable to a variety of configurations.

PHYSICAL CHARACTERISTICS:

Assembly area size:	7.3m W x 12.2m L x 18.3m High bay (24' x 40' x 60')
Outside entry door:	12.2m W x 12.8m H (40' x 42') Outside to high bay

CRANE ACCESS: The area is served by two bridge cranes which span the width of the building wing, approximately 15.2m (50'):

Double hood crane:	2,722 Kg (3 ton)	hook height - 8.0m (26'4")
	18,144 Kg (20 ton)	hook height - 7.1m (23'2")
High bay crane:	1,814 Kg (2 ton)	hook height - 14.7m (48'2")

FIXTURING: The area is equipped with four cast steel precision assembly tables with a grid pattern of drilled and tapped holes in the surface. These tapped holes are used to position and clamp various flight components during mechanical assembly. One table stands alone, while the other three are configured in a "U" shape and are used to accurately align shuttle-sized structures during mechanical assembly. All tables are calibrated and certified to 0.178mm (0.007") total indicator reading, and maintained flat within 0.127mm (0.005").

Stand alone table:	1.82m x 3.05m (6' x 10')	15.2cm (6") hole grid pattern
"U" table (2 each):	1.82m x 5.49m (6' x 18')	10.2cm (4") hole grid pattern
"U" table (1 each):	3.05m x 3.05m (10' x 10')	10.2cm (4") hole grid pattern
Table thickness:	15.2cm (6") all tables	

2.2.1.2 SPACECRAFT ASSEMBLY CLEANROOM

DESCRIPTION: The Spacecraft Assembly Section maintains a cleanroom for assembly of mechanisms, smaller structures, and instruments. Its location adjacent to the high bay spacecraft assembly area in Building 5 provides a limited access, secure, environmentally controlled work area for critical hardware assembly and functional testing tasks.

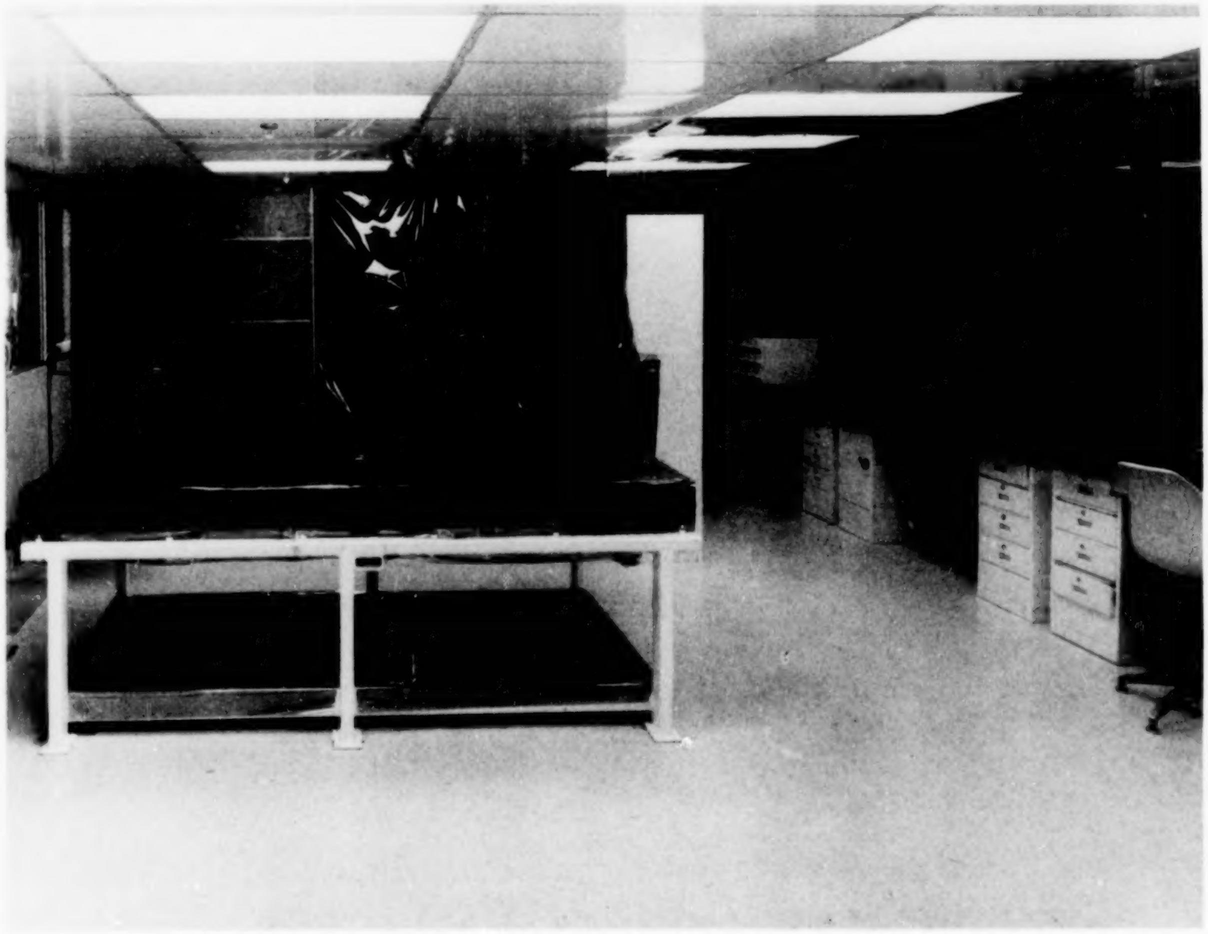
PHYSICAL CHARACTERISTICS:

Size:	6.1m W x 8.5m L x 2.3m H (20' x 28' x 7.5')
Access:	
Personnel door:	0.9m W x 2.1m H (3' x 7')
Equipment door:	3.1m W x 2.1m H (10' x 7')
Cleanliness level:	Class 10,000, 2.8m^2 (30ft^2) horizontal laminar flow wall module
Air flow:	31m/min (100 ft/min) velocity; 85m^3/min (3,000 ft^3/min) recirculating
Temperature control:	Air conditioned from 12.8° to 26.7° C (55° to 80° F)

ADDITIONAL FACILITIES:

Class 10,000, or better, laminar flow work bench with work volume enclosed in a plexiglass hood 122cm L x 66cm D x 97cm H (48" x 26" x 38")

Class 10,000 laminar flow cabinet enclosure, 91cm L x 41cm W x 48cm H (36" x 16" x 19")

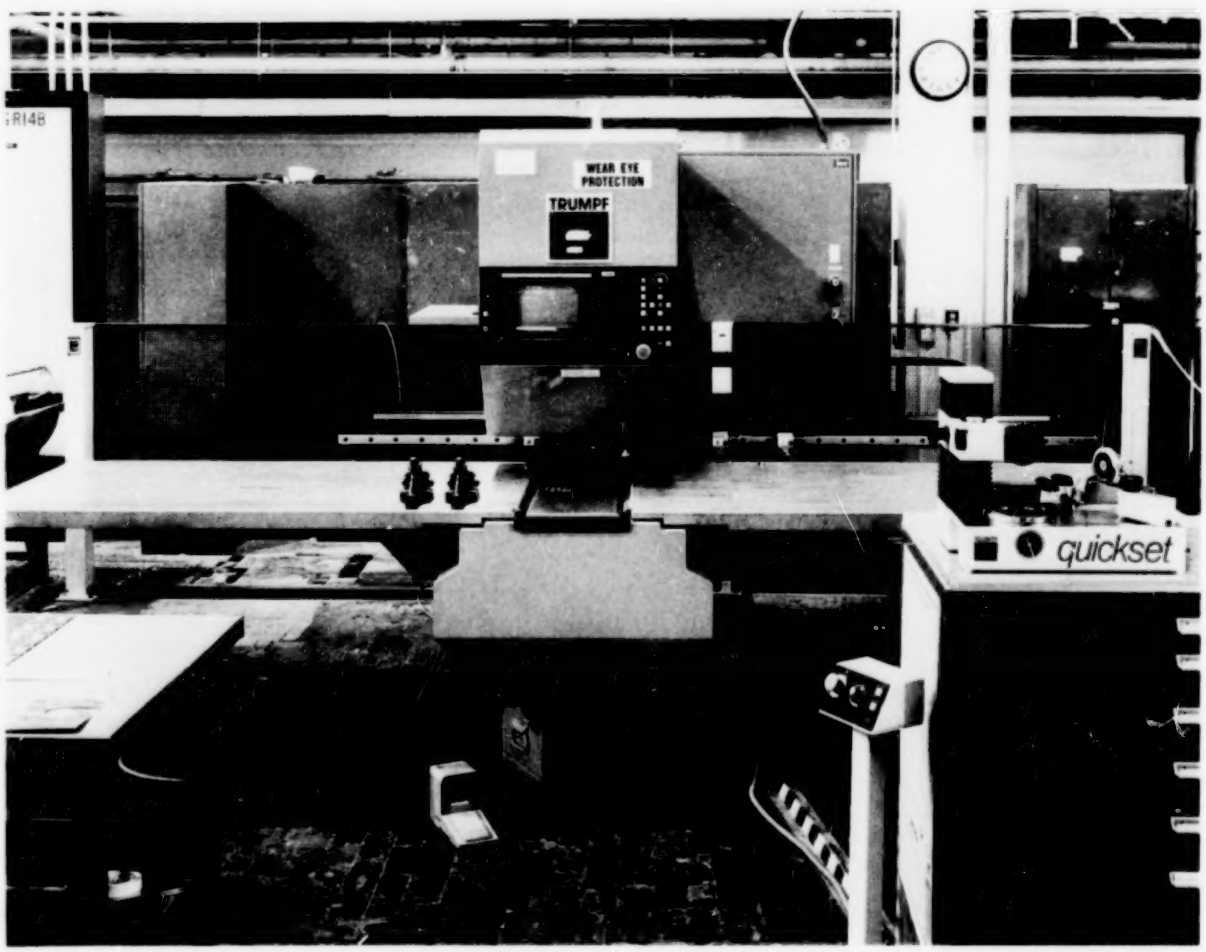


2.2.2 MACHINERY
2.2.2.1 TRUMPF TC 240 PUNCH

DESCRIPTION: This sheet metal machining center is a fully automatic CNC punching and contouring machine with interacting graphics part programming and storage.

MODE OF OPERATION: This machine has two methods of determining punch location, Cartesian and polar.

PARAMETERS: Punch location accurate to within 0.025mm (0.001"), repeatability to within 0.076mm (0.003"). Maximum punching force 245 K-newtons (27.5 ton). Maximum sheet thickness 6.35mm (0.25"). Nominal working range 201cm X and 99cm Y (79" and 39").

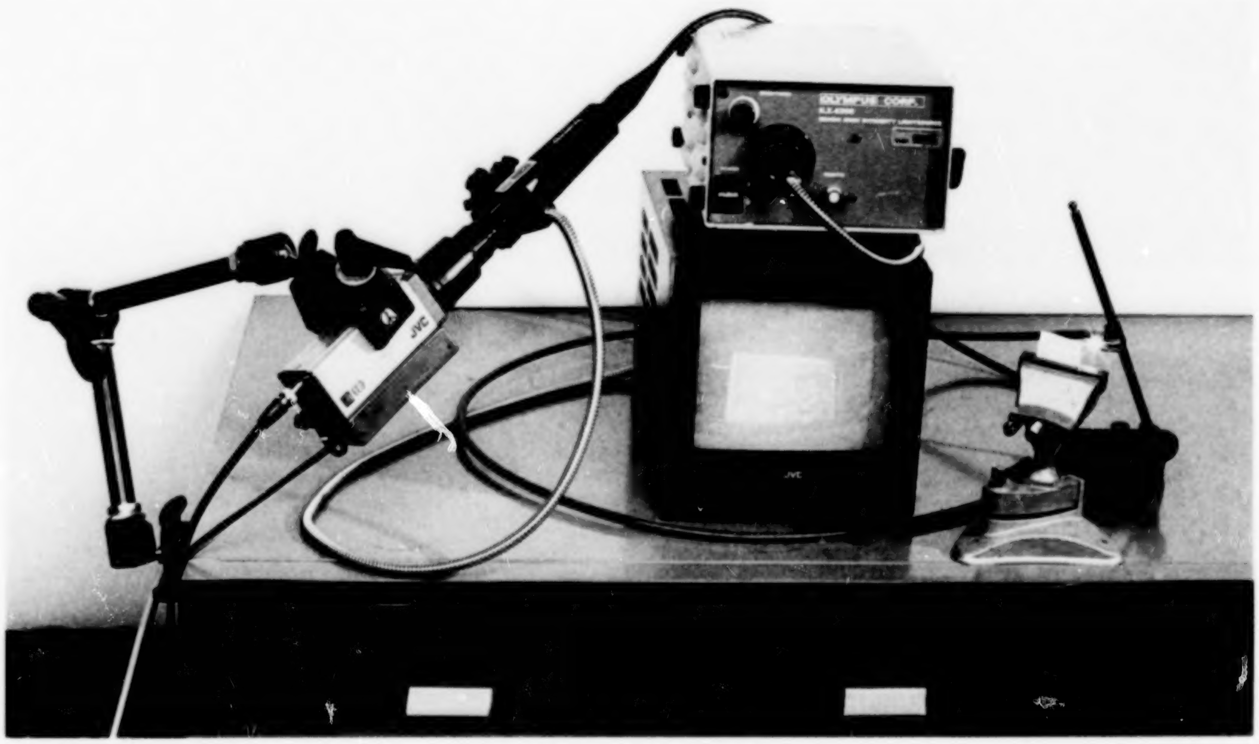


2.2.2.2 OLYMPUS FLEXIBLE FIBER-OPTICS SCOPE

DESCRIPTION: This scope is a visual tool used to examine or inspect otherwise unreachable areas of spacecraft structures and hardware. For example, it is used to inspect welds inside tubing or to inspect rivets during final closeout of a spacecraft.

MODE OF OPERATION: Wide ranging inspection tasks are conducted by connecting different adapters and attachments. These include the JVC color video system, portable VCR, Polaroid freeze frame video printer, ILX 6300 light source providing 6000 K color temperature, video keyboard, 35mm (1.38") camera body and a mini-borescope.

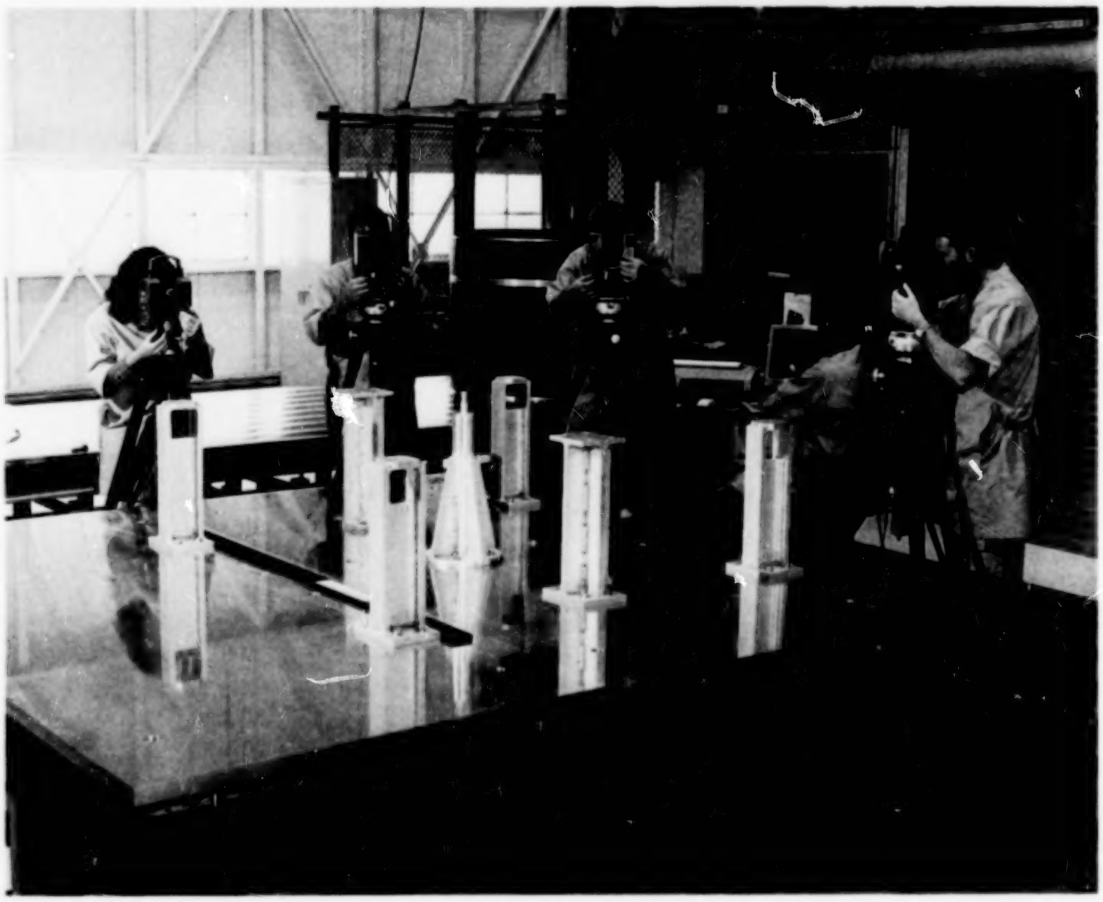
PARAMETERS: Fiberscope - 2.74m (9') length, field of vision - 40°, 4-way articulation - 120° up or down and 100° left or right, side view tip adaptor - 60°, direct view adaptor - 80°.



2.2.2.3 KERN 3-D MEASUREMENT SYSTEM

DESCRIPTION: The Kern electronic coordinate determination system (ECDS) is an optical/electronic industrial surveying apparatus. The main objective of industrial surveying is to construct, assemble, and align a work piece or component, as specified by the relevant drawings.

MODE OF OPERATION: In operation, from two to six electronic theodolites are aimed at reference datums on the object being measured. The theodolites transmit angular values directly to a computer which calculates the 3-D coordinates of the measured points. The coordinates of both surveyed points, and theoretical reference points, can be analyzed by the system to evaluate distance, straightness, flatness, and roundness. Functions are also available for computing lines, planes, circles, spheres, and parabolas. The theodolites can measure directions with an accuracy of between 0.3 and 0.6 seconds. At a target distance of 10m (32.8'), these angles correspond to an arc length of 0.02mm (0.0008").



2.2.2.4 RAYTECH PRECISION MEASURING TABLE

DESCRIPTION: This precision measuring table can measure part dimensions, hole-to-hole centers, and edge-to-hole distances. Mitutoyo manufactures the hardware and software used to derive and process measurements.

MODE OF OPERATION: The part is positioned on the table with one side flush to the reference bar. A probe is located directly below the part in a slot in the table. The probe is moved from the reference bar to the appropriate feature on the part, and a digital reading indicates the dimension. A printer is available to make hard copy outputs.

PARAMETERS:

Maximum part length:	264cm L (104")
Accuracy:	± 0.051mm (0.002")

2.2.2.5 DARLEY PRESS BRAKE

DESCRIPTION: The Darley press brake is used to bend metal sheet stock. The Darley has the capacity to form by bending various shapes and sizes of sheet metal items such as: chassis, angles, channels, and offset flanges, from most metals.

MODE OF OPERATION: The brake can be used in four different modes: manual, programmed, automatic, and step-by-step. Manual mode is used when doing just one bend. Programmed mode is used when a part is programmed and edited on the screen, or when down loading from a floppy disk. Automatic mode is used when a selected program is executed bend by bend. Both the hand and foot pedals can be used in all modes, and can be used together for maximum safety.

PARAMETERS:

Maximum forming force:	1.4M newton (160 ton)
Material Capacity:	0.64cm aluminum x 3.1m L (0.25" x 10')
Accuracy:	± 0.13mm (0.005") and 0.25°

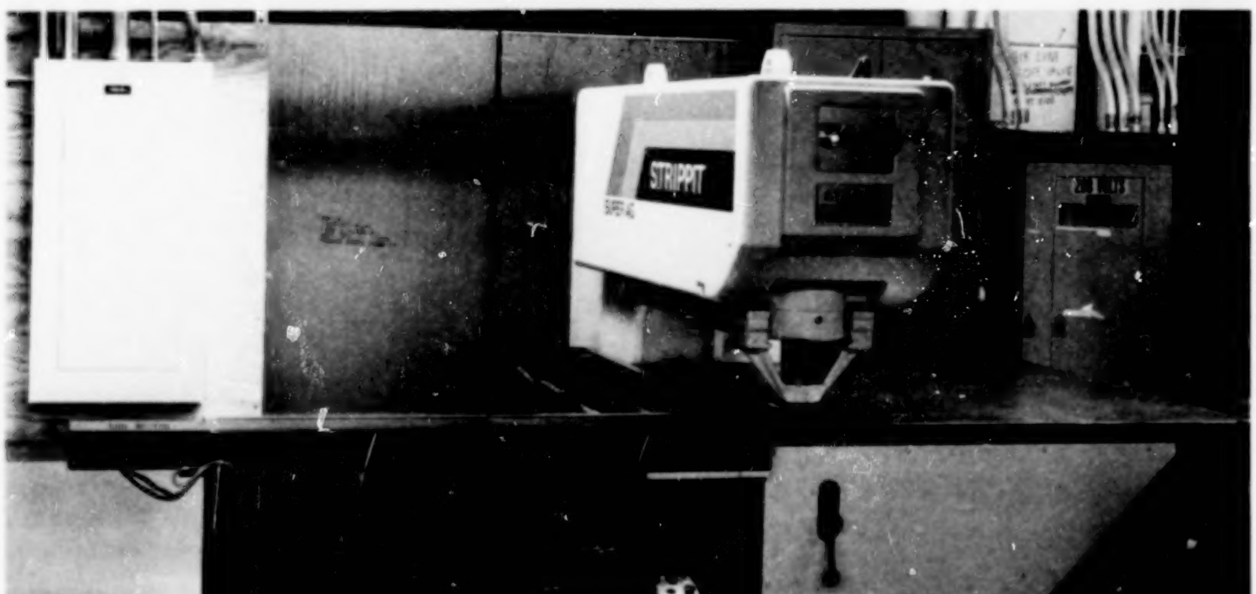
2.2.2.6 STRIPPIT SUPER 30-30 PUNCH

DESCRIPTION: The Strippit super 30-30 hole punching and notching machine is a single station, manually fed machine. It is used for punching holes, notching, and nibbling.

MODE OF OPERATION: This machine can be used in either the manual or auto-control mode. Manual mode can be used by simply entering the X and Y coordinates of the hole to be punched. The auto-control mode is used when patterns are needed to punch more complicated parts. The appropriate top punch and bottom die are selected and positioned in the tool holders. The part is placed flush against the X and Y stops and the foot pedal is depressed to initiate the punch. When operating in the auto-control mode, the machine will advance to the next punch, adjusting the X and Y stops appropriately.

PARAMETERS:

Maximum force:	267K newton (30 ton) on 0.79mm (0.031") thick steel
Material Capacity:	76cm x 76cm (30" x 30") for normal hole punching
Punched hole capacity:	0.79mm to 8.9cm (0.031" to 3.5") diameter



2.2.2.7 WYSONG SQUARING SHEAR

DESCRIPTION: This CNC squaring shear is designed to produce superior blanks at a high production rate. With its rugged construction, blade incline of 0.5°, fixed rake, and precision gauging, this shear offers superior edge condition and parallelism of parts within 0.025mm (0.001") per 31cm (12") of machine length. The shear can cut a full range of materials and thicknesses with no blade adjustment necessary.

MODE OF OPERATION: The shear is electro-mechanically operated with a pneumatically-controlled clutch.

PARAMETERS: The shear can cut aluminum sheet up to 11 gauge thick and up to 1.83m (6') long.

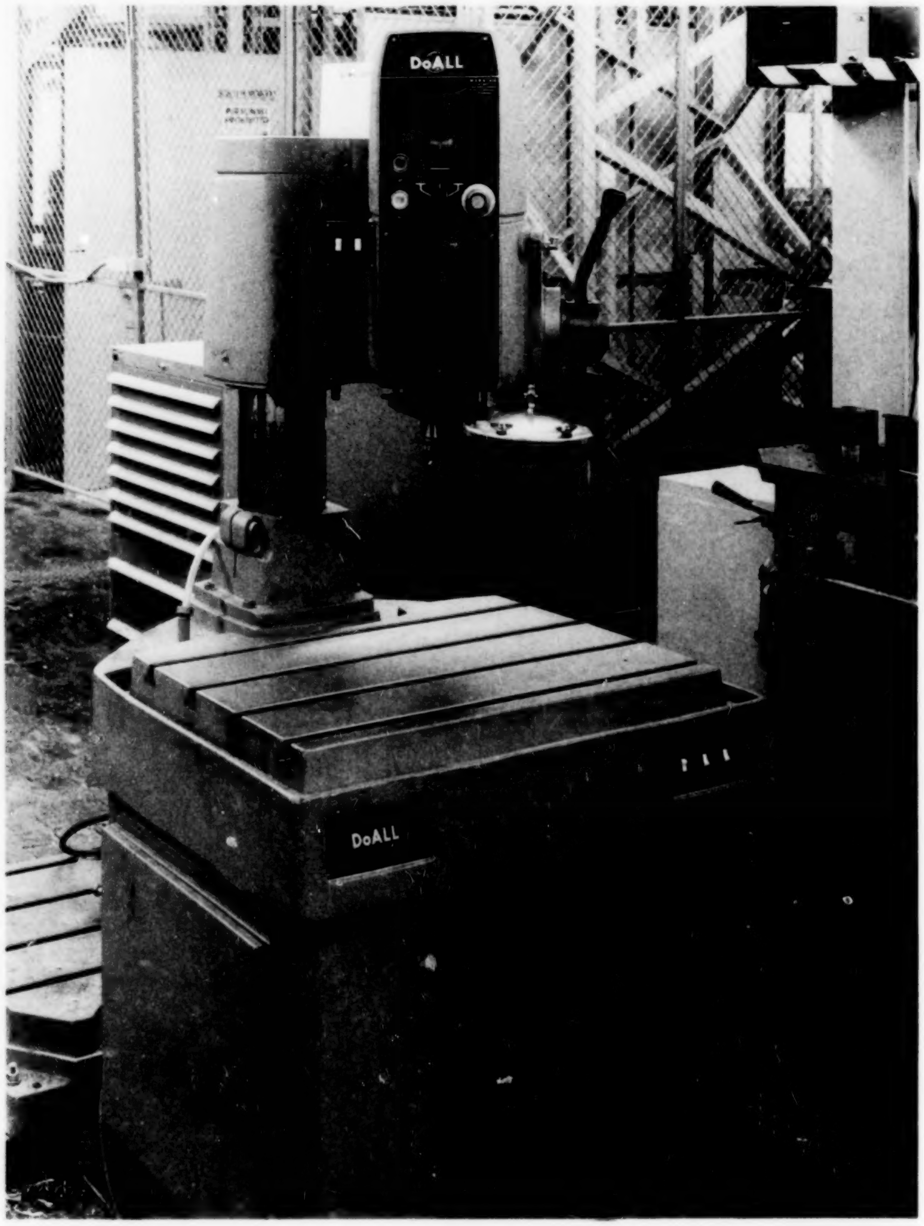
2.2.2.8 DO-ALL RADIAL ARM DRILL

DESCRIPTION: The Do-All drill is a heavy duty radial arm drill which can drill a wide variety of shapes and sizes using a wide range of drill sizes. It can drill and tap in any position up to 58.4cm x 88.0cm (23" x 34.625") without repositioning the work piece. The head and arm can be rotated 360° to perform off-the-table operations.

MODE OF OPERATION: Most movements of the drill are either electrically or mechanically operated. The head and arm swing movements are pneumatically operated.

PARAMETERS:

Spindle speed:	12 different speeds
Power feed:	3 different speeds

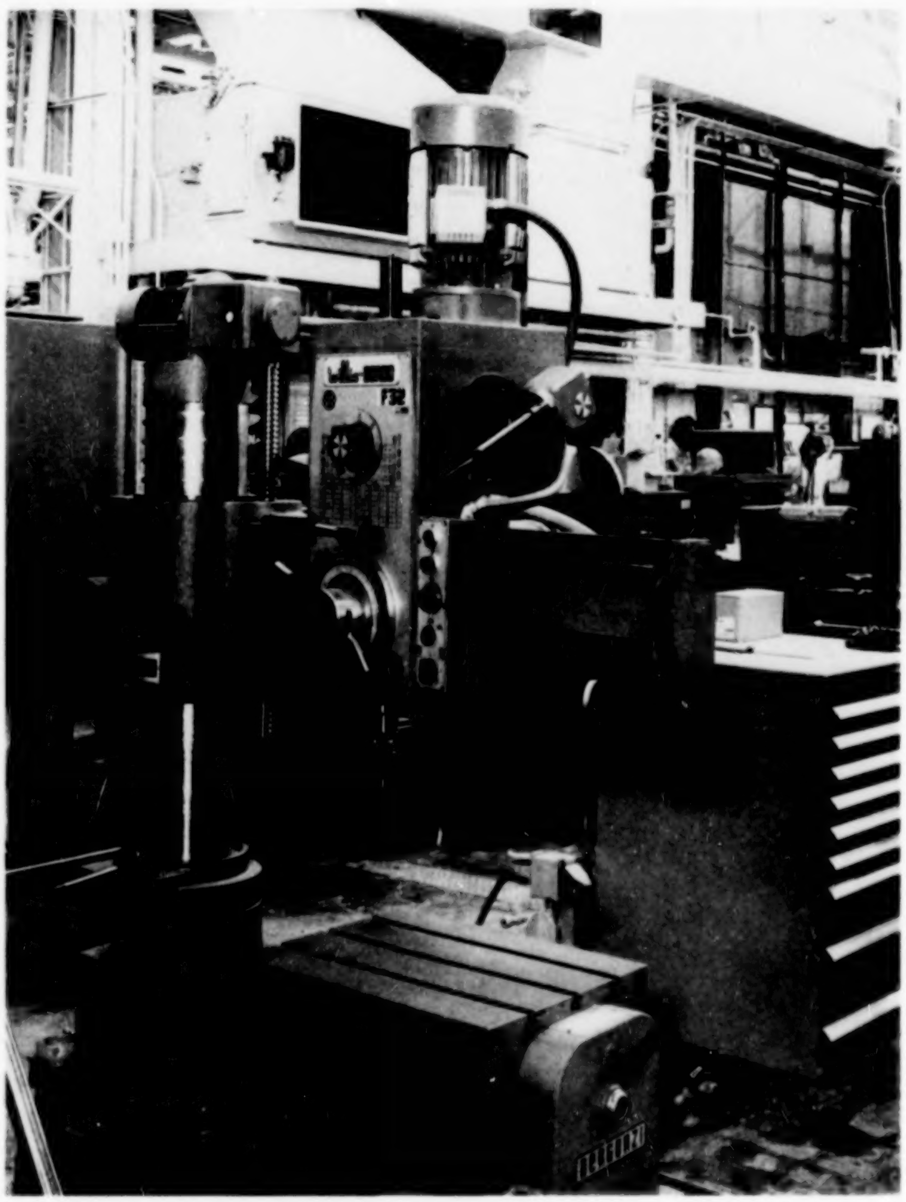


2.2.2.9 WILLIS BERGO DRILL

DESCRIPTION: The Willis Bergo drill is a heavy duty radial arm drill capable of drilling a wide variety of shapes and sizes with an equally impressive range of drill sizes. It has a universal tilting table which will accommodate drill angles from 0° to 90°.

MODE OF OPERATION: Most movement on this machine is either electrically or mechanically operated. The exception to this is the arm swing, which is manual.

PARAMETERS: This drill press has 12 spindle speeds, a 3-speed power feed, and is capable of drilling up to 6.35cm (2.5") diameter holes.



2.2.2.10 MONTGOMERY ROLLER

DESCRIPTION: The Montgomery roller is a four-roll, 12 gauge, 11.4 cm (4.5-inch) diameter roller metal forming machine. The four-roll configuration reduces the "flat" that is consistent with this type of forming.

MODE OF OPERATION: This machine has adjustable rolls for handling different material thicknesses, and also for applying variable pressure to the metal being formed.

PARAMETERS:

Material capacity:	0.953cm (0.375") thick
Material width:	127cm (50") for metals 12 gauge and less

2.2.2.11 DAKE PRESS

DESCRIPTION: The Dake press is an electrically and hydraulically operated hardware installation tool. It is used to install rivets, fasteners, eyelets, spacers, studs, nuts, stand-offs, and other type, associated hardware.

MODE OF OPERATION: The press operates by an electric motor driving a hydraulic pump to produce the desired, regulated, force. It includes: 1) A movable table which allows overhead loading of heavy work pieces; 2) an adjustable work head height which provides maximum daylight for oversized work; 3) a heavy duty hoist for handling work pieces; and 4) toggle clamps which lock the table securely in place.

PARAMETERS:

Force range: 0 to 667K newton (75 ton) ram force

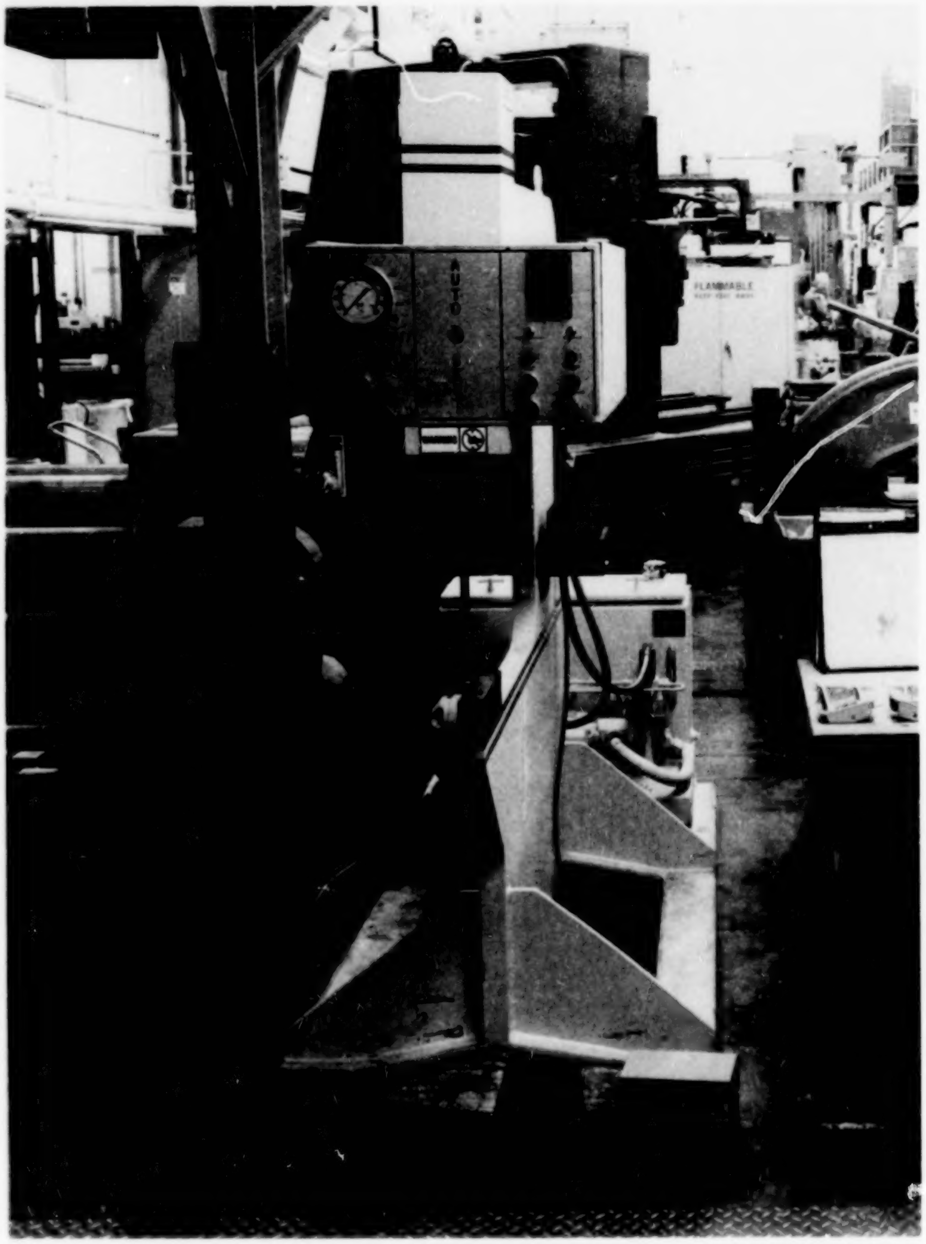
2.2.2.12 AUTO-SERT PRESS

DESCRIPTION: The Auto-Sert press is a hydraulically- and pneumatically- operated hardware installation tool. It is used to install hardware such as: rivets, panel fasteners, eyelets, spacers, studs, nuts, and stand-offs in flat or pre-formed metal assemblies. With tool changes, the press can punch holes in deep drawn cans, bend small sheet metal parts, and impression stamp.

MODE OF OPERATION: The press operates on regulated hydraulic and pneumatic pressure as opposed to the conventional "length of stroke" method.

PARAMETERS:

Force range:	0 to 91K newton (20,500 lb) ram force
Throat depth:	91cm (36")



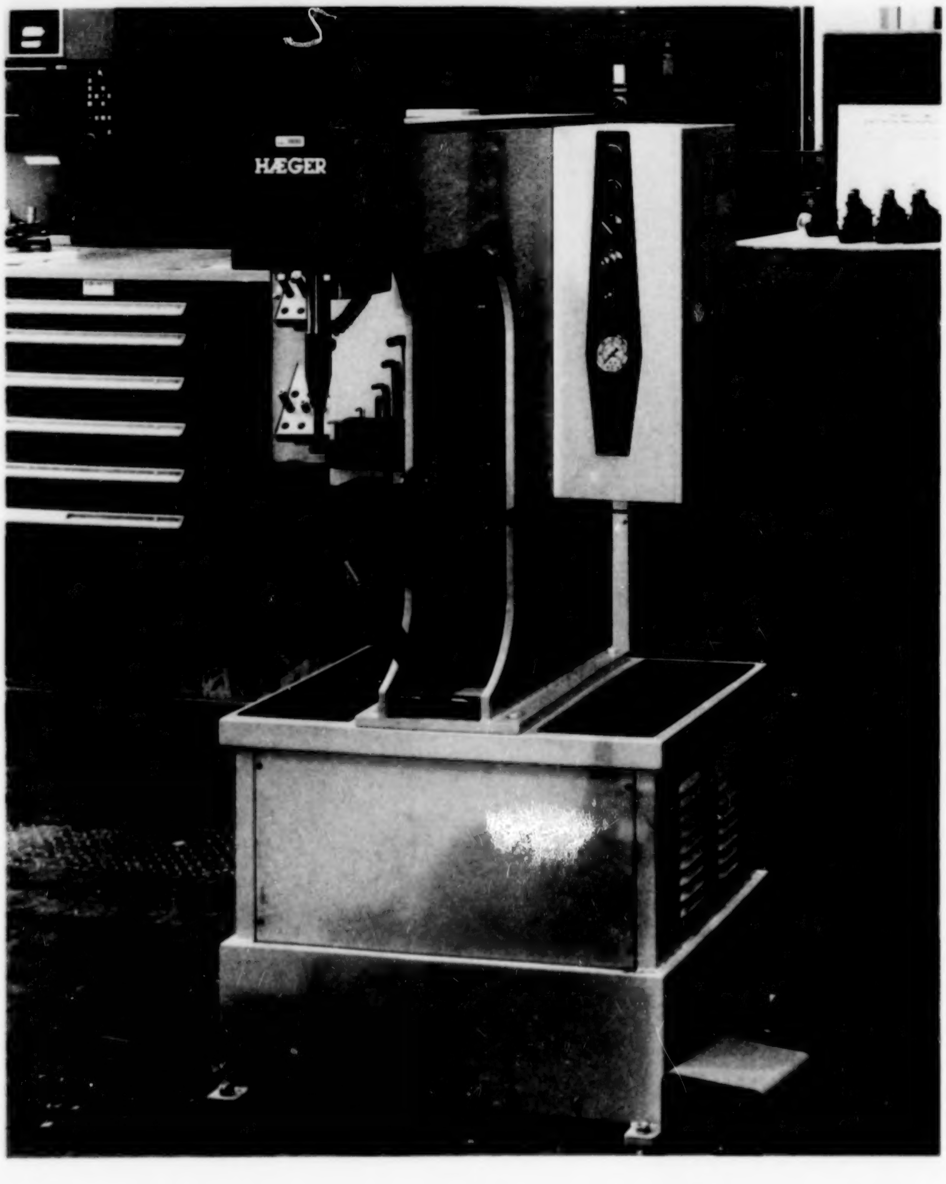
2.2.2.13 HAEGER PRESS

DESCRIPTION: The Haeger press is a hydraulically-operated hardware installation tool. It is used to install most major manufacturers' hardware such as rivets, panel fasteners, eyelets, spacers, studs, nuts and standoffs in flat or pre-formed metal assemblies. With tool changes, this machine also can punch holes in deep drawn cans, bend small sheet metal parts and impression stamp.

MODE OF OPERATION: This machine works on hydraulic pressure as opposed to the conventional "length of stroke" method. Once the machine is set to match the tooling, the pressure is regulated to acquire the end result.

PARAMETERS:

Force range: 0 to 53.4 K-newton (12,000 lb) ram force



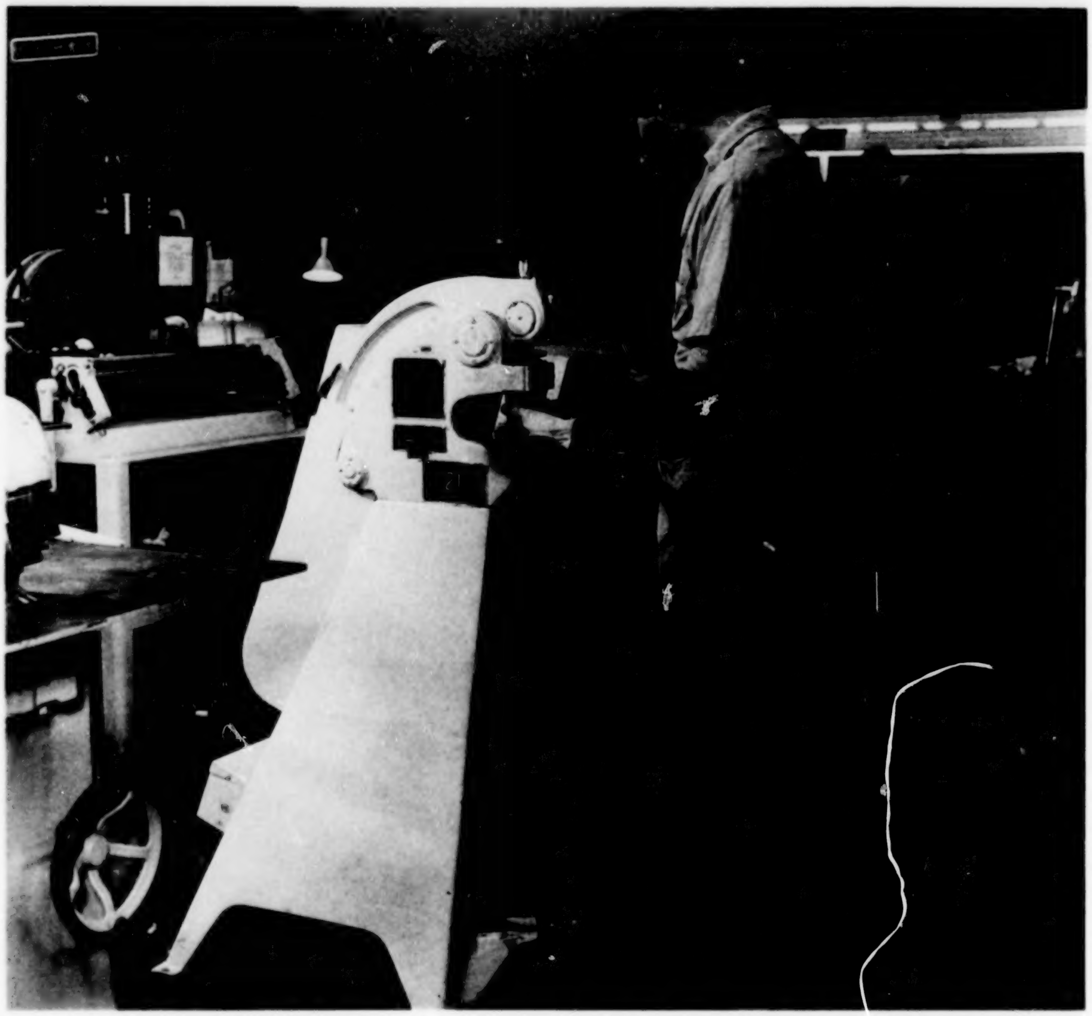
2.2.2.14 METAL SHRINKING AND STRETCHING MACHINE

DESCRIPTION: The purpose of this machine is to shrink or stretch metal in elongated areas through a series of local upsets. For experimental and prototype work, repairs, and small production lots, many shapes can be completely made eliminating the costly expenditures of production dies.

MODE OF OPERATION: Shrinking and stretching are accomplished by a series of local upsets performed by the vertical stroke of the upper and lower jaw sets powered by a fixed stroke air cylinder piston that is treadle operated.

PARAMETERS:

Maximum capacity:	6.35mm (0.25") thick
Materials:	Aluminum, stainless steel, titanium



2.2.2.15 SHEET METAL FORMING AND FLANGING MACHINE

DESCRIPTION: The Erco sheet metal forming and flanging machine provides a means of forming or flanging the edges of sheet metal where the contour is irregular, and hand work would otherwise be required. Forms or templates are unnecessary. This machine is used where production requirements do not justify the use of power press and die equipment.

MODE OF OPERATION: Power for the Erco machine is supplied by a one-horsepower, hand-switch control motor. All metal forming is accomplished by interchangeable die sets which are selected for the different forming requirements.

PARAMETERS:

Material capacity:	1.60mm (0.063") thick
Materials:	Aluminum, stainless steel, steel, brass, copper

2.2.2.16 NIAGARA RING AND CIRCLE SHEARS

DESCRIPTION: These shears cut circles, discs, holes and rings from blanks with utmost operating ease, speed and accuracy. Cutting may be started at any point on the inside or edge of the blank.

MODE OF OPERATION: The blank rotates while the cutters feed automatically. The depth of the cutter feed can be controlled manually or automatically. Power is supplied to the cutting operation by a foot treadle switch.

PARAMETERS:

Material capacity: 3.18mm (0.125") thick stainless steel

2.2.2.17 HYDRAULIC ANGLE BENDING MACHINE

DESCRIPTION: The Pullmax model Z31 pyramid type bending machine cold forms various shapes of different materials into curves and rings with a minimum of manual effort.

MODE OF OPERATION: Bending is accomplished between three rolls, two lower and one upper. All three rolls are mechanically driven, and the difference in peripheral speed required between the inside and outside of the profile being formed is compensated for by the upper roll being driven by a slip clutch. The lower rolls can be adjusted hydraulically and independently of each other. The machine can be used in either the vertical or horizontal position. The drive motor is a reversible brake motor.

PARAMETERS:

Bar stock:

Maximum size:	4.45cm (1.75") square
Minimum bend diameter:	40.6cm (16")

Angle:

Maximum size:	7.6cm W x 7.6cm L x 9.53cm T (3" x 3" x 3.75")
Minimum bend diameter:	91cm (36")

Flat stock:

Maximum size:	12.7cm W x 2.5cm T (5" x 1")
Minimum bend diameter:	40.6cm (16")

Tee stock:

Maximum size:	10.2cm W x 7.6cm L x 0.953cm T (4" x 3" x 0.375")
Minimum bend diameter:	71.1cm (28")

NOTE: The above sizes are based on steel

2.2.3 WELDING

The welding laboratory within the Spacecraft Assembly Section maintains a capability to perform metal joining and heat treating services. Metal joining for spacecraft applications consists of both manual and automatic gas-tungsten arc welding, manual and vacuum brazing, and soldering. Five technicians are currently certified to the qualification requirements of Military Standard 1595 for aircraft, missile and pressure vessel welding. Inspection services can be arranged on test articles for which metal joining services were provided. X-ray, fluorescent penetrant, or other nondestructive tests and certification documentation can be provided. Mechanical destructive testing of weld coupons can also be arranged.

The laboratory is equipped with the following conventional equipment for manual welding:

- Two stationary Miller Synchrowave 300-ampere AC/DC power supplies for tungsten-inert gas welding
- A Miller 50-ampere precision AC/DC power supply for welding foil or miniature components
- A portable Airco 300-ampere AC/DC square wave power supply can be used for field repairs
- A portable Miller synchrowave 300-ampere AC/DC power supply
- A portable Airco 250-ampere DC metal-inert gas welding system
- A portable Hobart 250-ampere DC motor-generator arc welder
- A portable plasma-arc metal burning (cutting) system

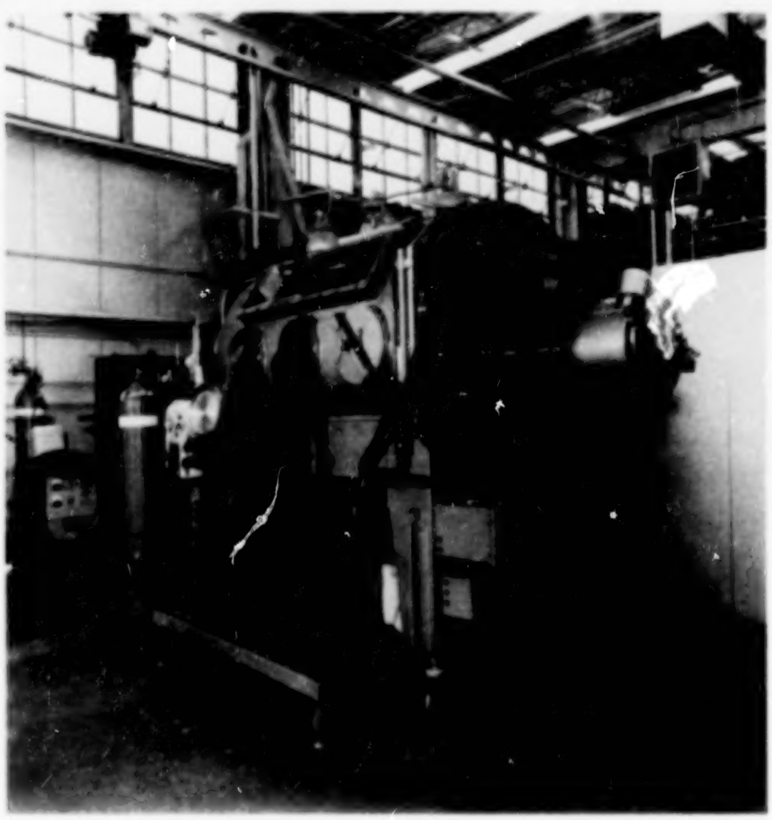
2.2.3.1 INERT GAS WELDING CHAMBER

DESCRIPTION: This aluminum chamber has three work stations on each side with rubber gloves. It is equipped with vacuum pumps on the bottom to evacuate the chamber, electric dryers to dry and remove moisture from the atmosphere, and recorders for vacuum and dew point readings. Metals welded in this chamber are those which cannot be welded in normal atmosphere. One of these metals is titanium.

MODE OF OPERATION: The chamber is evacuated with the vacuum pump and then backfilled with an inert gas of either argon or helium to one atmosphere. A 300-ampere AC/DC welding power supply is connected through tight feedthru plugs with a HW20 welding tig torch inside the chamber. The operator works through glove ports and views the part to be welded through the window in front. A dark welding glass is placed on the window in front of the operator to protect him from ultraviolet light rays. An ampere foot control is placed on the floor in front of the chamber so the operator can increase or decrease the heat input to the weld.

PARAMETERS:

Chamber size:	1.52m L x 1.22m diameter (5' x 4')
Viewing window:	0.91m L x 0.23m W (36" x 9")



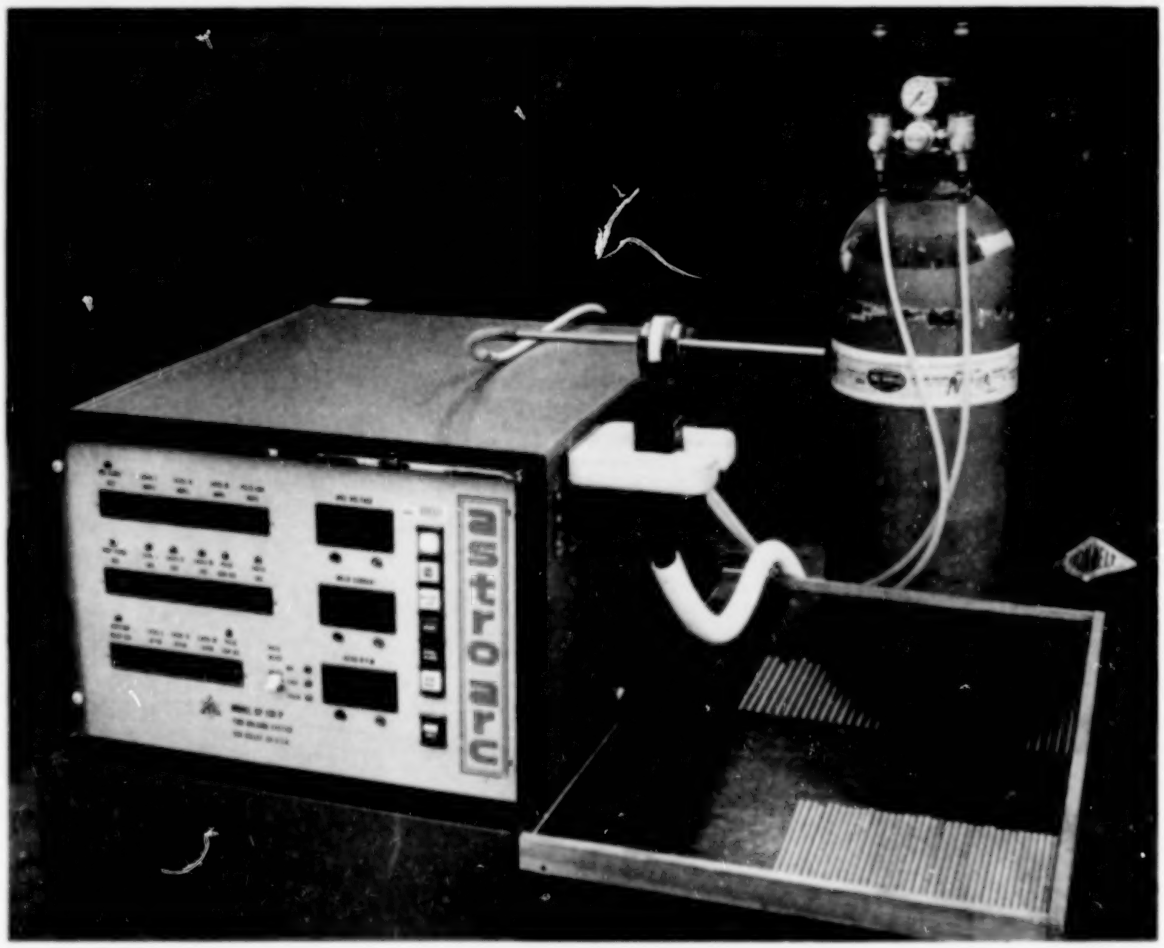
2.2.3.2 ASTRO ARC AUTOMATIC TUBE WELDER

DESCRIPTION: The Astro Arc model SP 100 tube welder consists of a power supply and control cabinet with arc voltage meters, speed control meters, weld current meters, and a programmable memory which can be set up to weld various sizes and types of metal tubing. It is equipped with many sizes of welding heads. This machine has excellent repeatability and is used for welding spacecraft hardware.

MODE OF OPERATION: The welding head separates into two halves and then is placed around the tubing joint to be welded. The head has a tungsten electrode which rotates inside the head and around the joint to be welded. The machine is programmed at a given speed and heat necessary to make a high quality weld. Inside the head, an inert gas flows to protect the electrode and the weld in progress.

PARAMETERS:

Range of tube sizes:	0.318cm to 3.81cm diameter (0.125" to 1.500")
Power supply capacity:	100 amperes



2.2.3.3 JETLINE SEAM WELDER

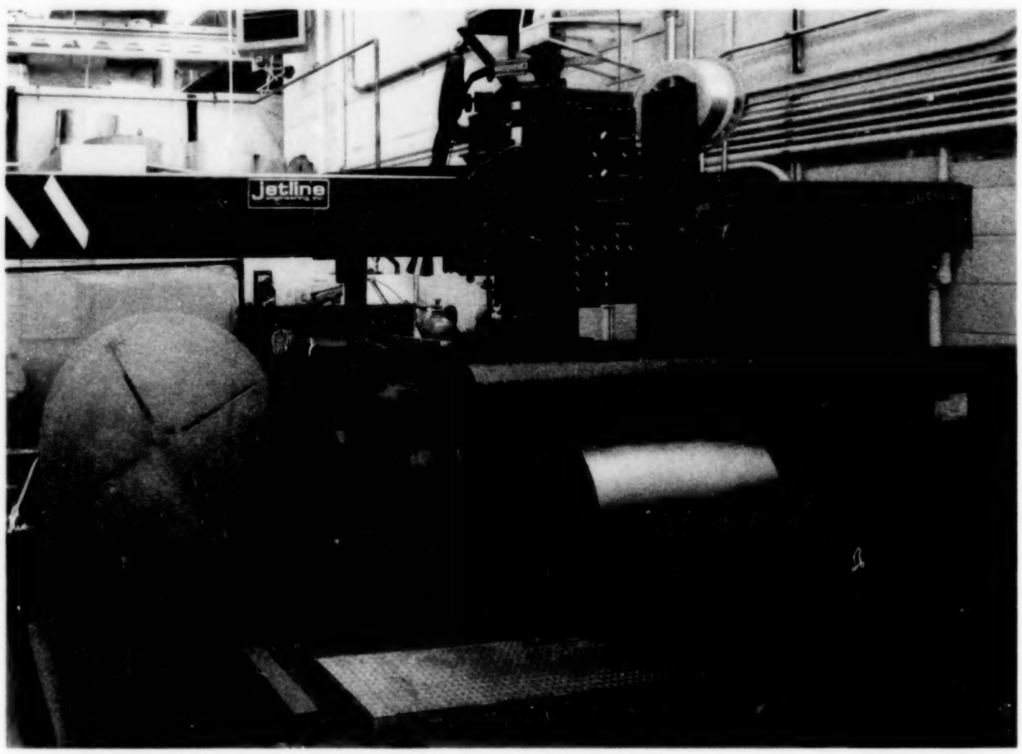
DESCRIPTION: The Jetline seam welder can longitudinally weld piece parts of any regular configuration including flat sheets, plates, cylinders, and cones. The machine makes welds which are free from imperfections and are of X-ray quality.

MODE OF OPERATION: The Jetline uses a positioner which provides backup mandrels of assorted sizes for material thickness, and two parallel banks of a level-seeking gripper finger. A tungsten inert gas (TIG) torch is mounted on a side beam carriage, and is motor driven down a track assembly on the positioner. The TIG torch is controlled either automatically or manually.

PARAMETERS:

Size of piece:	Up to 122cm (48") L x 94cm (37") diameter
Metal thickness:	0.25mm to 6.4mm (0.010" to 0.250")
Metals:	Aluminum, magnesium, steel, stainless steels, titanium

INTEGRAL INSTRUMENTATION: The seam welder includes precision instrumentation for ensuring X-ray quality welds. The 300-ampere AC/DC power source has both amp and volt meters, fine and course current adjustment, pre-flow and post-flow gas adjustments, and a programmer for automatic welding. The carriage and torch have speed adjustments for track movement and wire feed.



2.2.3.4 VACUUM FURNACE

DESCRIPTION: The Abar vacuum furnace is a horizontal chamber containing a vacuum heat zone shrouded with a water jacket. The furnace has three supporting systems: 1) inert gas supply, 2) heat exchanger, and 3) electrical control cabinet. It is also supported by a vacuum roughing pump, diffusion pump, and Welch holding pump.

MODE OF OPERATION: Where vacuum brazing of components or instruments provides greater metallic reinforcement or bonding, the process is implemented as follows. The part is thoroughly cleansed before it is fixtured in place by clamps or tack welding. After application of braze filler material of foil, powder, or pre-formed rings, the part is placed inside the heat zone and instrumented with thermocouples. The furnace is evacuated and then heated to the melting temperature of the braze material. When brazing is complete, the furnace is maintained at a vacuum during cooling, or it may be gas cooled.

PARAMETERS:

Power supply:	120 KVA, 460 volt, 3 phase, 60 Hertz
Brazing & heat treatment:	
Temperature range:	Room temperature to 1315° C (2400° F)
Size of part:	Up to 61cm W x 46cm H x 91cm D (24" x 18" x 36")
Vacuum range:	1.33 x 10^{-3} pascal (10^{-5} torr)
Size of heat zone:	61cm W x 46cm H x 91cm D (24" x 18" x 36")
Metals:	Stainless steel, titanium, copper, aluminum, gold, silver, molybdenum

INTEGRAL INSTRUMENTATION: The inert gas supply is used for gas quenching when heat treating various metals. The heat exchanger circulates the inert gas and cools the heat zone to room temperature. The electrical control cabinet functions as a power control, temperature chart recorder, heat zone temperature controller (automatic or manual), vacuum readout gauge, and vacuum recorder.

ADDITIONAL NOTES: Special features include automatic pumping cycle, manual/programmed heating cycle, recirculated gas cooling system, and partial pressure control system.

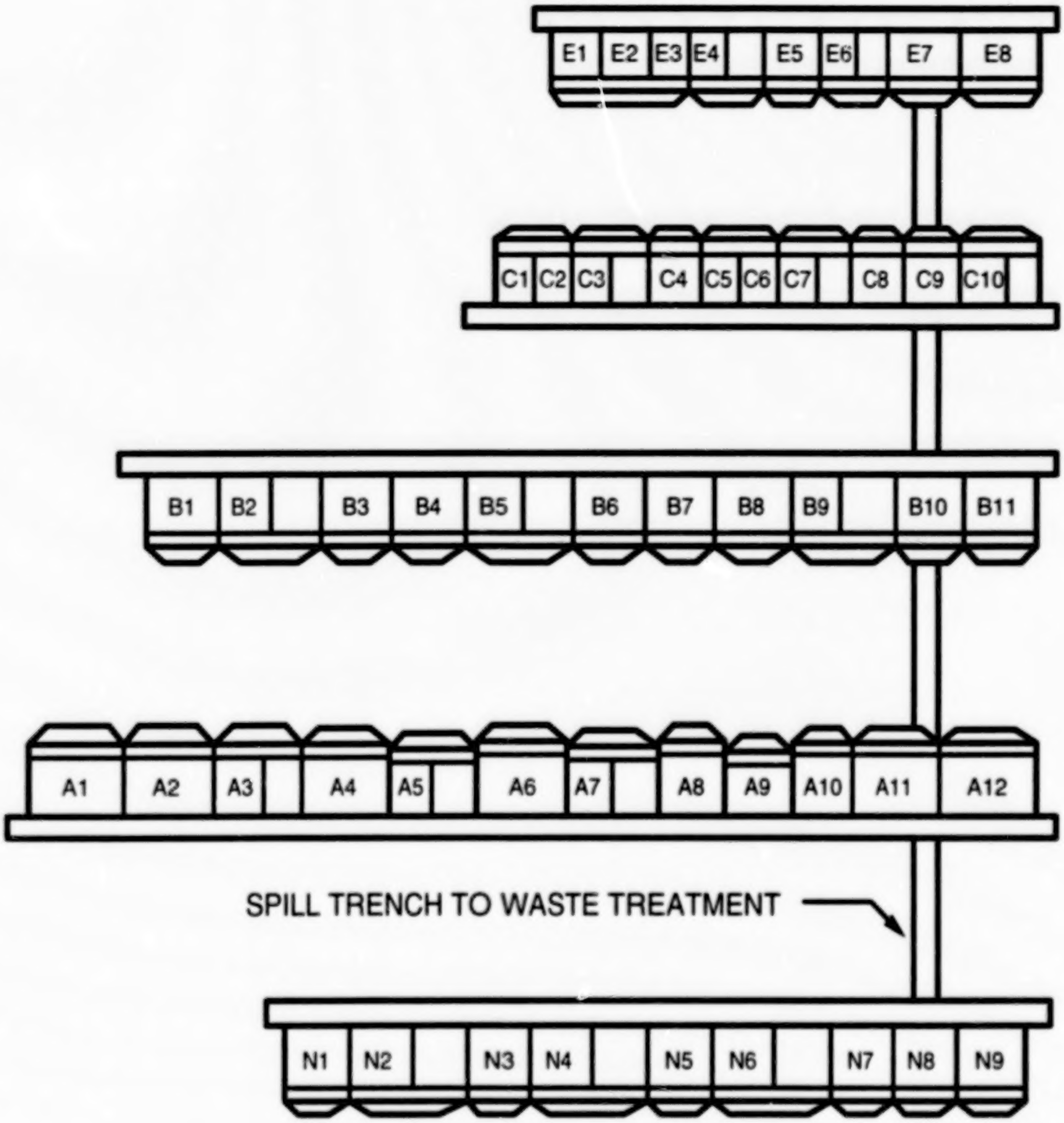
2.3 PLATING AND PLASTICS

The electrochemical processing laboratory provides services such as electroplating, cleaning, surface finishing, electroforming, chemical milling, composite manufacturing, and photofabrication techniques. Such services facilitate the construction, assembly, and modification of spacecraft and flight hardware, experimental instrumentation and ground support equipment. In addition to standard types of electroplating, the laboratory also has the capabilities of anodizing and iriditing aluminum and aluminum alloys.

The Plastics Laboratory provides plastic and elastomer technology and fabrication services for constructing, assembling, and modifying spacecraft hardware, experimental components, and laboratory instrumentation. It has capabilities for potting, encapsulating, coating, fiberglass layup, bonding, plastics forming, and developing engineering presentation models.

PLATING CAPABILITIES

PROCESS	SOLUTION	SPEC RANGE	PLATE RANGE	TANK SIZE
Electroless Nickel	$NiCl_2$, $NiSO_4$, NaH_2PO_2	Mil-C-26704 B ASTM Standard NI-P B733	Autocatalytic Reaction	235 liter (62 gal)
Black Nickel	$NiSO_4$, $NiSO_4(NH_4)_2SO_4$ $ZnSO_4$	Mil-C-18317	0.06-0.22 amp/dm^2 (0.5-2.0 amp/ft^2)	379 liter (100 gal)
Nickel	$NiSO_4$, $NiCl_2$	QQ-N-290 A	2.2-8.8amp/dm^2 (20-80 amp/ft^2)	454 liter (120 gal)
Copper	$CuSO_4$, H_2SO_4	Mil-C-14550 B	5 amp/dm^2 (45 amp/ft^2)	454 liter (120 gal)
Gold	BDT - 510	Mil-C-45204 E	0.33 amp/dm^2 (3 amp/ft^2)	454 liter (120 gal)
Iridite	Chromate Comp Iridite #14-2	Mil-C-5541 E	Immersion	606 liter (160 gal)
Anodize	H_2SO_4, 15% by weight	Mil-A-8625C	14-18 volt	568 liter (150 gal)
Silver	AgCN, KCN	QQ-S-365D	2.2-5.5 amp/dm^2 (20-50 amp/ft^2)	235 liter (62 gal)
Electro-Polishing	H_3PO_4	Non-Mil Spec Typ. Dim. Change: 0.005mm (0.0002")	0.62-0.23 amp/cm^2 (4-1.5 amp/in^2)	454 liter (120 gal)



PLATING BATHS LEGEND:

LINE E: ELECTROLESS NICKEL
LINE C: CYANIDE
LINE B: COPPER PLATING
LINE A: ANODIZE
LINE N: CUSTOM BATHS

A918.001

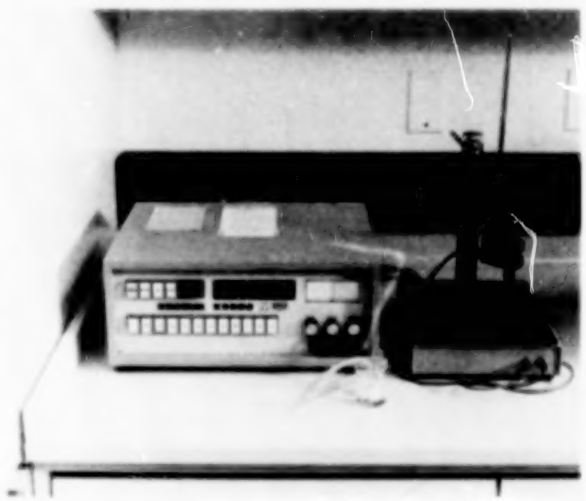
PLATING FACILITY BATHS BLOCK DIAGRAM

2.3.1 PLATING ANALYSIS LABORATORY

DESCRIPTION: The laboratory was designed to provide analysis of plating baths, thickness coating measurements, and thickness and sealing quality testing of anodic coatings.

MODE OF OPERATION: In compliance with engineering and military specifications, the plating baths shall be chemically analyzed in order to control within proper limits the concentration of the pertinent constituents. The plating laboratory has the capability to analyze plating baths, adjust pH, and check temperature on a daily basis. Cathodic depositions are recorded to determine characteristics and thickness parameters of the plating bath. A test coupon is plated with the part for destructive testing as, for example, in the sealing quality test for anodic coatings. Instruments used are Kocour Thickness Tester, Kocour Hull Cell, X-Ray Fluorescence Spectrometer, Brinkmann 682 Titrator and Dermitron D-3000 Thickness Tester.

<u>**Kocour Thickness Tester:**</u> This instrument measures the quantity of electricity required to dissolve the coating anodically from a known and accurately defined area. The method employs a small cell filled with an electrolyte. A current applied to the cell and to the specimen shows a change of voltage when the coating is dissolved. Thickness range for gold: 2.54-3.81 micron (0.010-0.150 mil); any other metals: 25-51 micron (1.0-2.0 mil).



<u>**Kocour Hull Cell:**</u> The Hull Cell is a miniature plating unit designed to produce a cathodic deposit that records the character of electroplate obtained at all current densities within the operation range. The Hull Cell shows the effects of metallic or organic impurities, addition agents, current densities, metal distribution, throwing power, temperature, and pH on plating solutions.

X-ray Fluorescence Spectrometer:
This instrument determines the thickness of both metallic and non-metallic coatings. The measurement of coatings by X-ray is based on the combined interaction of the coating and substrate with incident radiation of sufficient energy to cause the emission of secondary radiation characteristic of elements composing the coating and substrate. The X-ray tube has a potential of 50 KV for most thickness measurements.

Thickness Measurement Range (Upper Limit)

Application	Microns	µ-Inches
Silver	50.8	2000
Gold	7.6	300
Cadmium	63.5	2500
Copper	24-30.5	950-1200
Nickel	24-30.5	950-1200
Zinc	38.1	1500
Tin	76.2	3000

Brinkmann Model 682 Titrator: This instrument is a potentiometric titrator. It operates similarly to the normal chemical titration except that the end point is indicated by a change of potential of an electrode immersed in a solution.

Dermitron D-3000: This instrument measures the thickness of an anodic coating on aluminum. It measures the change in apparent impedance of the coil inducing the eddy current in the base metal. Thickness range: 0-838 micron (0-33 mil).

2.3.2 PLATING FACILITIES

DESCRIPTION: In compliance with engineering and military specifications, the electroplating shop provides electro-chemical processing of spacecraft and instrument components to guard against oxidation and to provide for requisite thermal and electrical conductivity, and electrical resistivity. Baths for cleaning, iriditing, anodizing, and plating processes are maintained daily. This shop works closely with the Spacecraft Assembly and Machine Fabrication Groups.

MODE OF OPERATION: Work is initiated through the Fabrication Management Office. Depending on the type of chemical processing required, the work is either done in the Goddard facility or, if necessary, it may be sent to a local contractor. The Goddard capabilities include gold, silver, copper and nickel plating, electroless nickel coating, black nickel coating, zincating, anodizing and iriditing. In addition to these processes, the electroforming of metal and electropolishing of stainless steel is performed.

Maintenance of the electroplating shop on a daily basis by solution analysis allows for continuous proper operation. Periodic disposal of waste solutions is carefully controlled and monitored at all times in compliance with local and Federal Regulations.

PARAMETERS:

Electroplating:	Coating spacecraft instruments and components for specific applications (Au, Ag, Ni, Cu)
Electroforming:	Long term process which builds up metal
Iridite coating:	Prevents oxidation, allows electrical conductivity
Anodizers:	Commonly used to meet thermal requirements of emissivity and absorptivity

PHYSICAL CHARACTERISTICS:

Gold plating:	17m L x 15m W (56' x 50')
Gold room:	3.45m L x 4.83m W (11'4" x 15'10")
Analytic Lab room:	6.5m L x 9.1m W (21'4" x 30')
Instrumentation room:	3.8m L x 2.6m W (12'6" x 8'8")
Storage area:	14m L x 19m W (47' x 63')
Buffing room:	4.9m L x 3.7m W (16' x 12')

2.3.2.1 COPPER PLATING

DESCRIPTION: The copper plating facility provides two different processes: 1) The copper cyanide process is an undercoating or "strike" (thin metallic coating) used to improve adhesion for aluminum, steel, and zinc die castings before plating with nickel or acid copper. The copper cyanide deposit provides good, smooth coverage and buffs easily. 2) The acid copper process provides uniform, bright, ductile, free from stress, and fine grain deposits. It is used as an undercoating for nickel plating and electro-forming, because of its good leveling and buffing properties.

MODE OF OPERATION: For all copper processes: 1) The part is degreased using an aqueous solution. 2) The physical soils are removed in an ultrasonic cleaning bath. 3) Metal-oxide films are removed by strong acids. 4) A thin metal "strike" is electro-deposited upon the part to improve adhesion. If the part is aluminum, steel, or zinc die casting, the copper cyanide process is used for striking the part. 5) After striking, the part is copper plated in an acid bath. 6) Between every step of the process, the part is thoroughly rinsed in a water bath.

PARAMETERS:

Copper Cyanide Bath	Acid Copper
Copper as metal: 15-30 g/liter (2-4 oz/gal)	Copper sulfate
Copper cyanide	Sulfuric acid
Sodium cyanide	Temperature: 24° to 32° C (75° to 90° F)
Sodium carbonate	Anode: copper phosphorized
Rochelle salt	Anode-to-cathode ratio: 2:1
pH: 10 - 11.5	Filtration: continuous
Temperature: 54° C (130° F)	Current density: 8-11 amp/dm^2 (70-100 amp/ft^2)
Current density: 2-6 amp/dm^2 (20-50 amp/ft^2)	Time to deposit 0.0025mm (0.0001"): 30 minute
Tank voltage: 4-6 volt	Agitation: vigorous
Agitation: mild; Time: 15 second to 1 minute	
Anode: copper oxide free; Anode-to-cathode ratio: 1:1 to 2:1	

PHYSICAL CHARACTERISTICS:

Characteristic	Copper Cyanide	Acid Copper
Rectifier	input: 115 VAC, 8 amp output: 12 VDC, 100 amp	input: 115 VAC, 8 amp output: 12 VDC, 200 amp
Anode	copper	copper phosphorized
Heater	stainless steel	teflon
Capacity	454 liter (120 gal), 91cm x 61cm x 91cm (36" x 24" x 36")	454 liter (120 gal), 91 cm x 61cm x 91cm (36" x 24" x 36")

2.3.2.2 GOLD PLATING

DESCRIPTION: The gold plating facility plates 24K gold on parts with a wide range of sizes. This system has two major components: 1) 454 liter (120 gallon) gold strike bath; and 2) 454 liter (120 gallon) gold BDT 510 bath. The gold plating facility provides uniform, bright deposits. They are relatively hard, yet ductile, have excellent solderability, and their non-crystalline structure and lack of organic films provide superior electrical integrity.

MODE OF OPERATION: The part is received with its drawing and/or any specifications for the gold deposit to be plated upon it. All gold plating follows this general process: 1) The part is degreased using an aqueous solution. 2) Physical soils, e.g., dirt are removed in an ultrasonic cleaning bath. 3) Metal-oxide films are removed in an activation process. This usually involves an acid dip of one type or another, depending on the metal being plated. Heavier oxide "scales" are removed in an acid solution. 4) A number of thin metal "strikes" are usually electro-deposited upon the part to improve adhesion of the gold plate. A "strike" of gold is then placed upon the part to prevent contamination of the pure gold bath, and again to facilitate adhesion of the final 24K gold plate. 5) The part is gold plated in the 454 liter (120 gallon) BDT 510 tank. 6) Between every step of the plating process, the part is thoroughly rinsed in a water bath.

PARAMETERS:

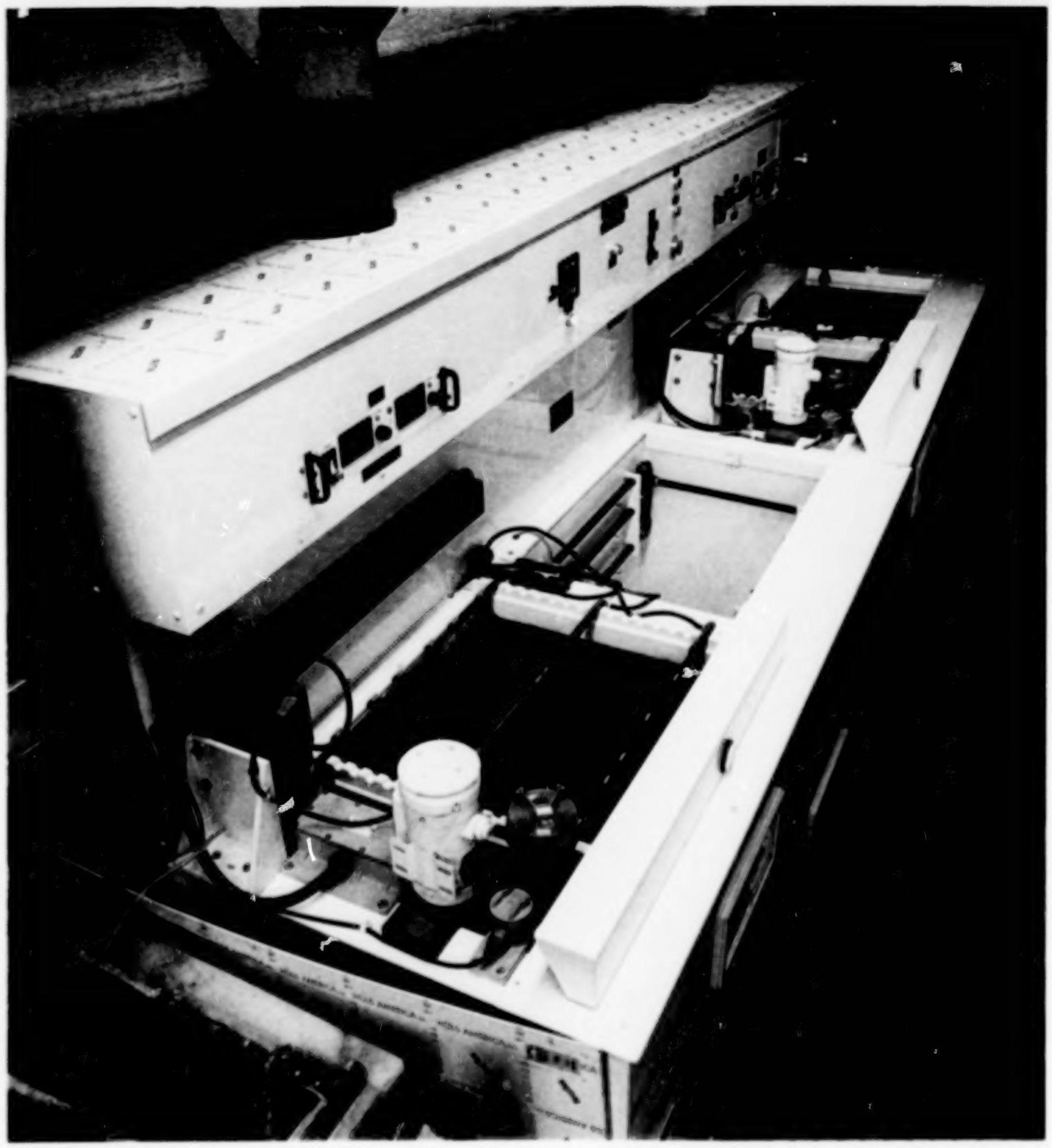
Parameter	AUROBOND TN Strike Bath	Parameter	BDT 510 Plating Bath
Bath	454 liter (120 gal)	Metallic gold content	8 g/liter (1.0 tr oz/gal)
Metallic gold content	1.6 g/liter (0.2 tr oz/gal)	pH	8.5
pH	3.5	Specific gravity	10° Baume (minimum)
Specific gravity	15° Baume (minimum)	Temperature	49° C (120° F)
Temperature	54° C (130° F)	Agitation	vigorous
Agitation	moderate	Anode	platanium
Anode	platanium	Anode-to-cathode ratio	2:1 or higher
Anode-to-cathode ratio	2:1	Cathode current density	0.33 amp dm^2 (3 amp/ft^2)
Cathode current density	1.1 amp/dm^2 (10 amp/ft^2)	Time to deposit 0.0025mm (0.0001")	13 minute
Time	15 sec up to 1 minute	Plating rate	120 mg (0.004 oz)/amp

PHYSICAL CHARACTERISTICS:

Rectifiers: 1) 454 liter (120 gallon) BDT 510 bath. Input: 8 amp, 115 VAC, Output: 50 amp, 10 VDC
2) Strike bath. Input: 8 amp, 115 VAC, Output: 10 amp, 10 VDC

BDT 510 baths: Modular system consists of:
1) 454 liter (120 gallon) capacity, 91cm L x 61cm W x 91cm Deep (36" x 24" x 36")
2) Aurobond TN strike capacity 454 liter (120 gallon)

INTEGRAL INSTRUMENTATION: 1) Analytical processor for gold concentration. 2) Hull cell for bath control. 3) X-ray fluorescence for coating thickness.



GOLD PLATING BATH

2.3.2.3 SILVER PLATING

DESCRIPTION: The silver plating facility plates deposits in a wide range of industrial applications at thicknesses ranging from 0.51mm to 1.52mm (0.02" to 0.060") or higher. The process produces a hard, ductile, and uniform deposit that is smooth and free of nodules.

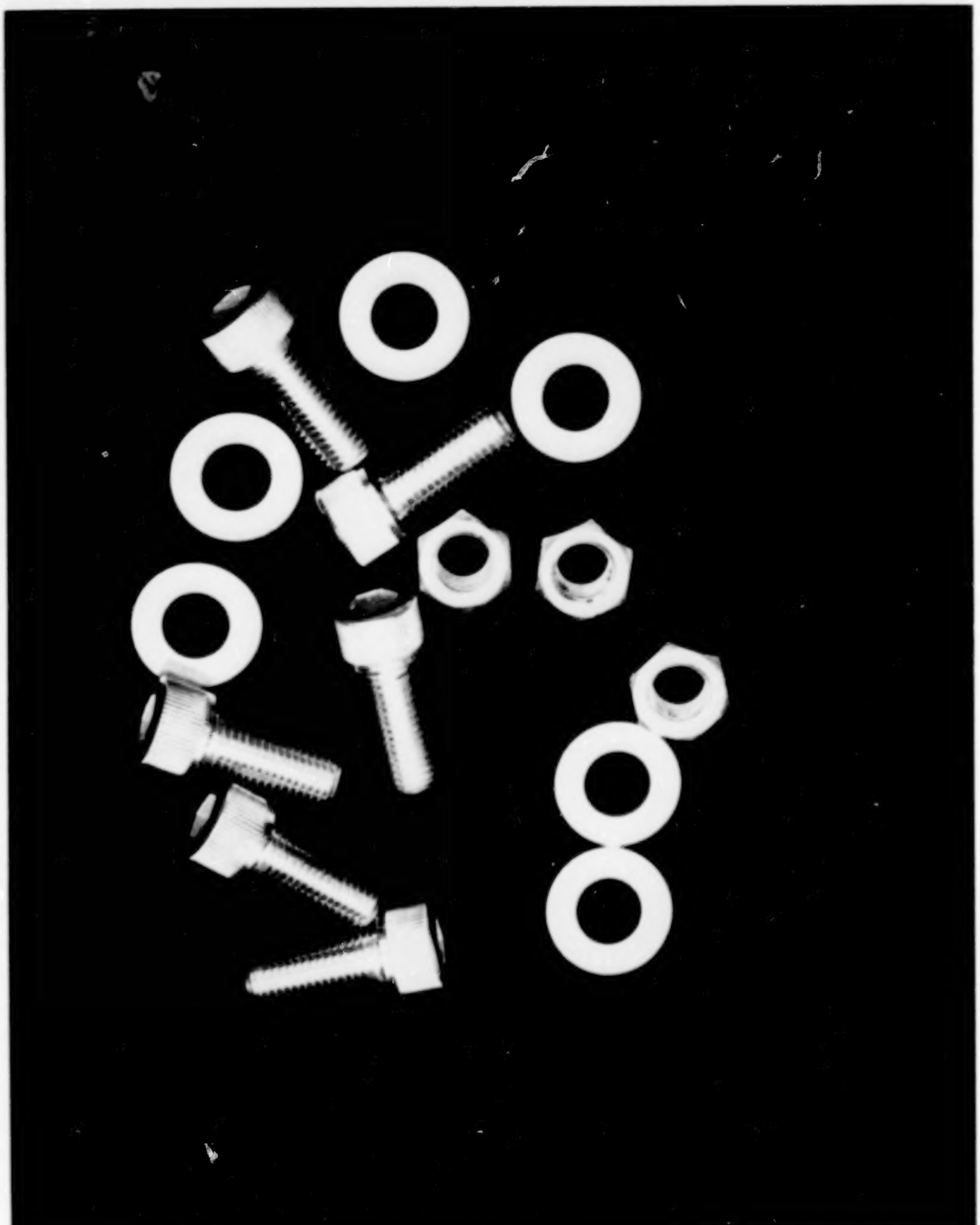
MODE OF OPERATION: 1) The part is degreased using an aqueous solution. 2) Soil is removed in the ultrasonic cleaning bath, and metal oxide films are removed in an activation process. 3) A number of thin metal "strikes" are electro-deposited upon the part for adhesion; the base metal determines the type of "strike". 4) A silver "strike" is then applied to improve adhesion. 5) The part is silver plated in the 189 liter (50 gallon) industrial silver bath. Between every step of the process, the part is thoroughly rinsed in a water bath.

PARAMETERS:

Parameter	Silver Strike	Parameter	Industrial Silver Bath
Bath size	235 liter (62 gal)	Bath size	189 liter (50 gal)
Silver cyanide	4.5 g/liter (0.6 oz/gal)	Silver as metal	75 g/liter (10 oz/gal)
Potassium cyanide	83 g/liter (11 oz/gal)	Potassium cyanide	75 g/liter (10 oz/gal)
Temperature	-12° to 29° C (10° to 85° F)	Potassium carbonate	15 g/liter (2 oz/gal)
Anode	stainless steel	Industrial Brightened	1.1 cc/liter (4 cc/gal)
Cathode density	1.7 to 2.8 amp/dm^2 (15 to 25 amp/ft^2)	Temperature	18° to 27° C (65° to 80° F)
Time	15 second	Cathode current density	3-6 amp/dm^2 (25-50 amp/ft^2)
		Filtration	intermittent
		Anode	silver
		Anode-to-cathode ratio	2:1 or higher
		pH	12.5
		Time to deposit 0.0025mm (0.0001")	1.2 minute

PHYSICAL CHARACTERISTICS:

Characteristic	Silver Strike Bath	Characteristic	Industrial Silver Bath
Size	235 liter (62 gal)	Size	189 liter (50 gal)
Rectifier	input: 120 VAC, 15 amp output: 12 VDC, 100 amp	Rectifier	input: 120 VAC, 15 amp output: 12 VDC, 100 amp dual range, PP
Anode	stainless steel	Anode	silver (6)



SILVER PLATED FASTENERS

2.3.2.4 NICKEL PLATING

DESCRIPTION: The nickel facility plates a wide range of nickel deposits. The system is comprised of four different processes: 1) The Wood's nickel process is a "strike" (thin metallic coating) used to improve adhesion on stainless steel, nickel, invar and titanium. 2) The Watt's nickel deposit has been developed for producing a hard, ductile and compressively stressed nickel deposit. 3) The electroless nickel deposit has a high phosphorous (10-12%) content. The deposits produce smooth, hard, and easy to solder surfaces. 4) The black nickel deposit is a dark, thin, nonreflective deposit that performs best over corrosion resistant coatings.

MODE OF OPERATION: For all nickel processes: 1) The part is degreased using an aqueous solution. 2) The physical soils are removed in an ultrasonic cleaning bath. 3) Metal-oxide films are removed by strong acids. 4) A thin metal "strike" is electro-deposited upon the part to improve adhesion. If the part is made of stainless steel, nickel, invar or titanium, the Wood's nickel process is used for striking the part. 5) After striking, the part is nickel plated with an electroless, Watt's or black nickel coating. 6) Between every step of the plating process, the part is thoroughly rinsed with water.

PARAMETERS:

Wood's Nickel	Watt's Nickel	Electroless Nickel	Black Nickel
nickel chloride	nickel 75 g/liter (10 oz/gal)	nickel sulfate	nickel sulfate
hydrochloric acid	nickel sulfate	sodium hypophosphite	nickel ammonium sulfate
temp: 21°-29° C (70°-85° F)	nickel chloride	nickel 6 g/liter (0.8 oz/gal)	zinc sulfate
curr. density: 6-17 amp/dm^2 (50-150 amp/ft^2)	boric acid	complexants, buffer, stabilizer	sodium thiocyanate
anode: nickel	pH = 3	temp: 38-97° C (100-206° F)	pH = 5.6-5.9
time: 0.5 to 5 minute	temp: 54° C (130° F)	pH = 4.8	temp: room
	current density: 2-9 amp/dm^2 (15-80 amp/ft^2)	Optimum loading: 25 to 245cm^2/liter (0.1 to 1.0 ft^2/gal)	Current density: 0.06-0.22 amp/dm^2 (0.5-2.0 amp/ft^2)
	filtration: continuous	plating rate: 10-13 micron/hr (0.4-0.5 mil/hr)	agitation: moderate
	anode: nickel	agitation: vigorous	
	agitation: vigorous	filtration: continuous	
		composition as phosphorous 10-12%	

PHYSICAL CHARACTERISTICS:

Characteristic	Wood's Nickel	Watt's Nickel	Electroless Nickel	Black Nickel
Size	307 liter (81 gal) 91cm x 61cm x 76cm (36" x 24" x 30")	454 liter (120 gal) 91cm x 61cm x 91cm (36" x 24" x 30")	235 liter (62 gal) 76cm x 61cm x 61cm (30" x 24" x 24")	379 liter (100 gal) 91cm x 61cm 76cm (36" x 24" x 30")
Rectifier	input: 115 VAC output: 6 VDC	input: 115 VAC, 8 A output: 12 VDC, 250 A		input: 115 VAC, 8 A output: 12 VDC, 100 A
Heaters		titanium		teflon heaters
Anode	nickel	nickel	N/A	carbon, nickel

NICKEL PLATED HARDWARE

2.3.3 PLASTICS

DESCRIPTION: The plastics facility provides assistance and technical information to Division personnel or other GSFC employees in the form of polymer and plastics manufacturing technology. The staff analyzes operational problems on existing experiments and instruments to determine if malfunctions or anomalies are related to material, design, or fabrication deficiencies. In addition, the staff recommends alternate approaches to design specifications. Specifically, protective enclosures, flight experiment components, and scale model mock-ups for wiring and cable harnesses are constructed in this facility.

MODE OF OPERATION: The plastic shop builds spacecraft components and instrument parts from plans and blueprints supplied by the engineering departments of GSFC. Fabrication of plastic scintillator wave guide assemblies, foam photo-tube cushioning containers, bonding of ceramic frames with epoxy compounds for gamma ray experiments, assembly and bonding metal and fiberglass booms for electric field experiments, are examples of work done in this shop. The shop performs all phases of buffing, polishing, machining, potting and joining of plastic, fiberglass, wood, and foam materials. The plastic shop is also responsible for engraving spacecraft and instrument components for identification, and as an aid in assembly procedures. The shop works with Spacecraft Assembly personnel in bonding actual space flight materials, and with thermal engineering personnel in fabricating and installing protective foam shield assemblies.

PARAMETERS: Acrylic or plexiglas, MC bond acrylic cement, RTV silicones, polyamide foams, and potting compounds are most commonly used in fabrication.

PHYSICAL CHARACTERISTICS: The facility consists of three rooms, one room for machining operations and two assembly rooms. Each room is approximately 93m^2 (1000 ft^2).

INTEGRAL EQUIPMENT: Table and radial saws, lathe, joiner, shaper, planer, milling machines, and engravers are used daily, to produce component parts for assemblies.

2.3.4 MODEL BUILDING

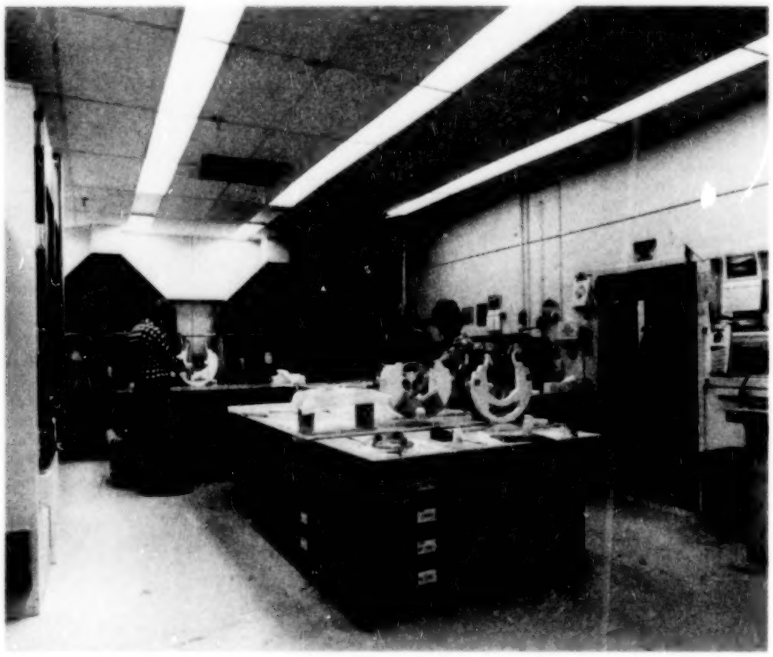
DESCRIPTION: A model building shop is maintained as part of the plastics facility. This model shop is responsible for the fabrication of scale models of spacecraft and flight instruments. It is also responsible for producing mock-up assemblies to assist in visual presentations of proposed projects.

MODE OF OPERATION: The shop's model designs originate from blueprints, artistic renderings, freehand drawings, or verbal and written instructions. After determination of materials and scaling of models, construction of component parts of the design begins. Upon completion of the parts, surface preparation, sanding, buffing, polishing, and painting precede assembly of the final product or model. The shop staff works closely with designers and engineering personnel during planning and fabrication.

PARAMETERS: Wood, plexiglas, brass, aluminum, sealants, cements, and similar materials are used in fabrication of models.

PHYSICAL CHARACTERISTICS: This facility shares space and inventory with the plastics group.

INTEGRAL EQUIPMENT: Jig saws, sanders, joiners, planers, ovens, bending and forming equipment are used in the fabrication of models.



2.3.5 COMPOSITES MANUFACTURING LABORATORY

DESCRIPTION: The laboratory is designed for process development, prototyping, and small spaceflight hardware production in composite materials, primarily fiber-reinforced plastics. It is also the center for structural adhesive bonding. The physical space will be superseded by a new fabrication facility in 1995, designed to produce Explorer-class instruments and spacecraft hardware in a contamination and humidity-controlled environment. Composite materials find great utility due to the technologist's ability to tailor a high specific stiffness, low coefficient of thermal expansion (CTE), and high thermal conductivity.

MODE OF OPERATION: Successful development and production of a composite component is a significant undertaking. Projects are initiated through the Fabrication Engineering Branch Head. A team of composite engineers and technicians from the Plating and Plastics Section work concurrently with design engineers, testing personnel, and others from various organizations to ensure successful design and manufacture. Technical personnel are available to advise projects at any stage of their development, and to assemble a team of experts from among our colleagues on center and throughout NASA and industry.

PARAMETERS: Graphite, glass, and kevlar fibers are the most commonly used reinforcement; and there are many grades of each, giving different values of strength, stiffness, CTE, and conductivity. Commonly-used matrices are epoxies and cyanate-esters. Thermoplastics and metals will be used occasionally. The raw materials are laid up on a mold and cured with heat and pressure to near-net-shape. Then finish machining and surface preparation for bonding are performed. Adhesive bonding is the primary joining technique for assembly, and mechanical fasteners are often supplementary.

PHYSICAL CHARACTERISTICS: The facility consists of one room of approximately 93m^2 (1,000ft^2) with temperature and humidity control, plus an autoclave and a milling machine at remote locations. The new facility (in 1995) will be a total of 372m^2 (4,000ft^2) and will include a 102m^2 (1,100ft^2), class 10,000 cleanroom for adhesive-bonded assembly, with a 4.5Kg (5 ton) crane and 7.6m (25ft) hook height. It will be unique in its ability to maintain a low humidity, with control to as low as 20% RH.

INTEGRAL INSTRUMENTATION:

- Autoclave: 0.91m x 1.83m (3' x 6')
- Programmable control laminar flow convection oven, 1.22m x 1.22m x 0.61m (4' x 4' x 2'); recirculating air or exhaust
- Data acquisition system
- Integrally-heated tool fabrication work bench
- Exhaust hood for etching and solvents
- Freezer storage for b-staged epoxy-impregnated fibers
- Vacuum supply, vacuum table
- All supplemental curing supplies
- Assembly tables and fixturing
- Bridgeport milling machine

COMPOSITES MANUFACTURING LABORATORY

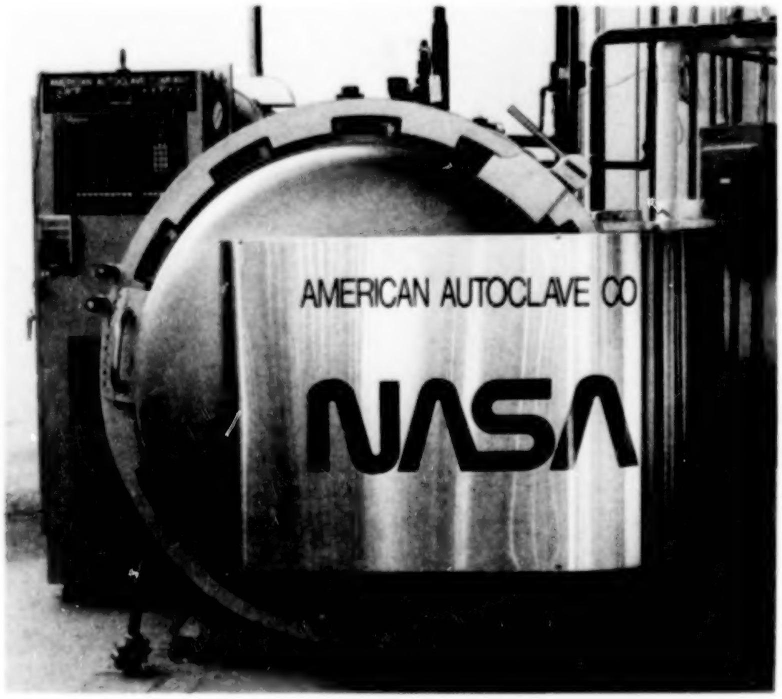
2.3.6 AUTOCLAVE

DESCRIPTION: The autoclave is the principal instrument in the cure of fiber-reinforced epoxy composites. The autoclave is a pressure vessel that is capable of controlled heating of a mold and laminate in a pressurized atmosphere. It applies a vacuum to the interior of the mold assemblage in order to draw off volatiles and to maintain the pressure differential between inside and outside. Commonly, a flexible sheet or bag covers the uncured laminate on the mold. With a vacuum applied to the laminate, and pressure applied to the outer surface of the bag, a consolidating pressure is applied to the laminate, pushing fibers and resin into place and compressing bubbles of any volatiles that remain.

MODE OF OPERATION: Thermocouples are installed in the laminate or on the tooling (mold). Vacuum valves are installed in the outer sheeting (the vacuum bag) and attached through hoses to the vacuum system of the autoclave. The front-loading door is closed and sealed, and the chamber is pressurized with nitrogen. A vacuum is applied to the interior of the vacuum bag, and this vacuum bag is forced in upon the tool by the pressurized atmosphere, commonly about 586Kpa-690Kpa (85psi-100psi). The entire operation of the autoclave and the closed loop control of all curing parameters are computer controlled.

PARAMETERS:

Working space:	0.91m x 1.83m cylinder (3' x 6')
Temperature (max):	315°C (600° F)
Pressure (max):	1.379Mpa (200 psi)
Control system:	Honeywell 9000 controller
Supervisory station:	Honeywell computer and chart recorder
Extra ports on chamber:	Feedthrough connectors for other sensors and power supply
Cure options:	Internally-pressurized bag



2.3.7 CAMERA FACILITY

DESCRIPTION: The camera facility consists of an AGFA Repromaster 310 camera, Macintosh IIx computer, Linotronic 200P photo-typesetter, and a Hermes Vanguard 6000 engraving system. The vertical camera is designed to make precision reductions and enlargements from 45 to 400 percent. The bulk of the art work is generated on the Macintosh IIx and Linotronic. Full-page lay-ups can be composed on the Macintosh 53cm (21") monitor. The high precision Linotronic typesetter produces copy from 300-to-1270 lines per 2.54cm (inch), and uses either film or paper to produce camera-ready art work.

The Vanguard 6000 engraver, controlled by a WIN 386sx computer, uses a variety of cutters from 0.25mm to 6.4mm (0.010" to 0.250"). There is also a diamond tool for scratch engraving almost any type of plastic or metal up to a 36cm x 152cm (14" x 60") panel.

MODE OF OPERATION: The art work is designed using the Mac IIx and printed on the Linotronic 200P. The negative or positive is taken to the darkroom and either printed on a metal photo plate or photographed using the camera. When printing to a metal photo plate, the plate is exposed from 4 seconds to 2 minutes duration using a NUARC arc lamp with a 1,000-watt mercury lamp.

PARAMETERS:

Camera film size:	51cm x 61cm (20" x 24")
Linotronic film size:	31cm (12") x infinite
Metalphoto size:	25cm x 31cm (10" x 12")
Engraving plate:	36cm x 152cm (14" x 60")

2.3.8 METAL PHOTO AND PHOTO ETCHING

DESCRIPTION: Metal photo and photo etched plates are fabricated in conjunction with the plating and camera facilities. The metal photo process uses an anodized aluminum plate with a photo emulsion already on it. The photo etched process is used for circuit boards and polished brass plates.

MODE OF OPERATION: Metal Photo: The metal photo process uses either a film negative or positive, normally produced by using a Macintosh IIx computer and a Linotronic 200P typesetter. The image is transferred to the metal plate by placing either the negative or positive onto the metal plate and exposing it with a high intensity arc lamp for about 10 seconds. The plate is developed by using a Zip processor for another 10 seconds, after which it is rinsed and hung to dry. After drying, it is dyed (if necessary) and immersed in a tank of boiling sealing solution for 30 minutes. Once sealed, the plate is polished and cut, and then mounted to a wooden base.

Photo Etching: In the photo etching process, a piece of brass is cut to size, polished, coated with a photo resist, and hung to dry for one hour. Next, the plate is baked for 30 minutes, and then exposed to a high intensity mercury lamp. The exposed plate is developed, rinsed, and baked again for another 30 minutes. In the next step, the plate is immersed in the ferric chloride etcher for 2 minutes, and then cleaned in a chromic acid solution. Finally, it is sprayed with lacquer to prevent oxidation.

PARAMETERS:

Product:	Size (maximum):
Metal photo	25cm L x 31cm W (10" x 12")
Brass plate	31cm L x 31cm W (12" x 12")
Circuit board	25cm L x 31cm W (10" x 12")

PHYSICAL CHARACTERISTICS:

Characteristic	Zip Processor	Etcher	Mercury Lamp	Oven
Model	14-4	Kepro	Nu Arc	230G
Size	62cm W x 22cm L x 11cm H (24.5" x 8.5" x 4.25")	15 liter (4 gal)	31cm x 61cm (12" x 24")	46cm x 48cm x 41cm (18"H x 19"W x 16"D)
Speed	10.5 RPM	N/A	N/A	N/A
Power	120 VAC, 60 Hz	120 VAC	120 VAC	230 VAC, 60 Hz, 725 w

7.3.9 TYPESETTER

DESCRIPTION: The typesetting Linotronic 200 system consists of a flatbed scanner to scan pictures or documents, a Macintosh personal computer to bring words and pictures together, and the Linotronic's imagesetter to produce the text and graphics on paper or film.

MODE OF OPERATION: The art work is designed in the camera facility by the use of the typesetting Linotronic 200 system. First, the scanner scans bound documents, without cutting them apart, producing an accurate and undistorted image. Then, the Macintosh computer creates high quality typeset documents and art work quickly and easily on the screen. The Linotronic 200 laser imagesetter integrates the high performance Macintosh image by using laser technology to produce the art work on film or resin coated paper.

PARAMETERS: The typesetting produces a displaced composition from 4.5 to 127 points in increments of 0.5 point. In addition, it has 22 type styles with 102 characters for each style. Maximum film or paper size is 31cm x 31cm (12" x 12").

2.3.10 ENGRAVING

DESCRIPTION: The Hermes Vanguard 6000 engraving system is used for engraving spacecraft parts and miscellaneous plates for the Goddard center. It is run by a 386 DX computer and has a digitizer and generic CAD, so almost any art work that can fit onto its table can be digitized and engraved.

MODE OF OPERATION: Engraving is accomplished by using a high-speed motor and various sizes of engraving tools from 0.25mm to 6mm (0.01" to 0.25"). A diamond tool is used for scratch engraving. Text to be engraved is typed into the computer and formatted for the proper font style, letter size, and text position. The job is held in place by using a vacuum engraving table which has a vise for holding irregularly-shaped parts.

PARAMETERS:

Capacity:	X-axis: 36cm (14"); Y-axis 31cm (12"); Z-axis 5cm to 15cm (2" to 6")
Engraving table:	31cm x 36cm (12" x 14")
Letter height:	up to 31cm (12")
Plate length:	up to 163cm (64")

ENGINEERING SERVICES DIVISION

FABRICATION USER'S GUIDE

ENGINEERING SERVICES DIVISION USER'S GUIDE OUTLINE

I. ESD USER'S GUIDE: FABRICATION

I. ESD USER'S GUIDE: FABRICATION

1.0 Introduction

The following pages present an overview of the fabrication and assembly services provided by the Engineering Services Division (ESD), Code 750. Included is a brief description of the organization along with the point of contact for those wishing to have fabrication and assembly work done. Following this is an overview of our facilities and capabilities. We have also included a list of documents required to obtain fabrication and assembly services as well as helpful hints and suggestions in order to make things easier for our customers and ensure the best service possible.

2.0 Organizational Responsibilities

The ESD, Code 750, is responsible for the overall management of Goddard Space Flight Center's (GSFC) fabrication and assembly facilities located in the Building 5 east wing high bay and various small satellite shops located in Buildings 2, 5, 10 and 22. Code 752.3, the Fabrication Management Section, is responsible for the overall scheduling, expediting, and final delivery of fabricated hardware. The remainder of Code 752 supports the Fabrication Management Section by evaluating fabrication methods, processes and equipment; and by developing new processes during fabrication and assembly of precision sheet metal structures, welding, plastic structures, electroplating and advanced composite structures. In addition, Code 751, the Machining Technology Branch, supports Code 752.3 by evaluating fabrication methods, processes and equipment, and by developing new processes while machining components and assembling small precision mechanisms. Much of our equipment is state of the art and operated by technicians with many years of technical training and on the job experience.

2.1 Organizational Contacts

In order to assist in the planning and expediting of a fabrication and/or assembly task, Figure 1 identifies the principal contact. This contact from the Fabrication Management Section, Code 752.3, can provide assistance in determining needed resources (funding, personnel and facilities) to accomplish the fabrication and/or assembly task.

2.2 Fabrication Management Section

The Fabrication Management Section has the overall responsibility to manage and coordinate the construction, assembly, and modification of flight spacecraft, balloon experiments, ground support handling and test equipment, and experimental components for laboratory instruments. This section is responsible for planning, estimating, scheduling, coordinating, and expediting all fabrication work; and introducing and applying advanced technology in the manufacturing field (in-house and commercially). Commercially performed services are provided by a series of contracts with approximately 35 small business companies in the Baltimore/Washington area. These services include machining, sheet metal fabrication, welding, heat treating, plastics fabrication, woodworking, model building, engraving, painting, electroplating, and assembly. The size and capabilities of

Figure 1. Code 750 Contacts For Fabrication and Machining

<u>Machining Technology Branch (Code 751)</u>

Fabrication & Development Section
Section Head (Code 751.1)
Bldg. 5-Rm. E235
(301) 286-5251

Computer-Aided Manufacturing Section
Section Head (Code 751.2)
Bldg. 5-Rm. C30A
(301) 286-6308

Instrument Support Section
Section Head (Code 751.3)
Bldg. 5-Rm. C30B
(301) 286-6289

<u>Fabrication Engineering Branch (Code 752)</u>

Spacecraft Assembly Section
Section Head (Code 752.1)
Bldg. 5-Rm. E38A
(301) 286-6453

Plating and Plastics Section
Section Head (Code 752.2)
Bldg. 5-Rm. C30D
(301) 286-5545

Fabrication Management Section
Section Head (Code 752.3)
Bldg. 5-Rm. C30F
(301) 286-5822

these companies vary from small (one and two person) shops to companies with over 90 employees. Shop capabilities range from small machines to machines large enough to produce shuttle-sized components.

3.0 Facilities Overview

The Machining Technology Branch and Fabrication Engineering Branch maintain a full range of facilities needed for the complete fabrication and assembly of space flight hardware. These facilities are located in-house (Building 5) and at local contractor's plants. These facilities support a variety of activities including conventional and computer numerically controlled milling and turning operations, wire and RAM electrical discharge machining (EDM), jig, cylindrical, and surface grinding, metal forming and punching, welding, mechanical assembly and integration, model making, advanced composite structure fabrication, electroplating, anodizing, painting, engraving, heat treating, dimensional inspection, dye penetrant inspection, and centralized fastener inventory.

4.0 Capabilities

4.1 Overview

The fabrication facilities are just a portion of Code 751 and 752 capabilities. The technical expertise of our people provide an invaluable knowledge base to the customer in order to produce the highest quality product possible. Our customers are encouraged to involve fabrication personnel early in the design process. The Fabrication Management Section personnel and Code 751 and 752 section heads are available to help our customers with their technical questions. The Machining Technology Branch and the Fabrication Engineering Branch have produced a group of videotaped seminars entitled, "Tutorials For Design Engineers", available for viewing at the GSFC Learning Center.

4.2 Design Producibility Review

The personnel in the Fabrication Management Section are available to coordinate design producibility reviews for our customers early in the design phase. A team of technicians with years of manufacturing experience evaluate the designs and make suggestions to the designers. These suggestions facilitate the fabrication process, particularly in the areas of cutting costs and expediting schedule.

4.3 Cost And Schedule Estimates

The Fabrication Management Section will provide cost and schedule estimates for one drawing, or a whole package of drawings, so that our customers can better plan their project.

4.4 Coordinating And Expediting Fabrication And Assembly

The personnel in the Fabrication Management Section prepare a Certification Log for the processing of the part from the engineering drawing through machining or sheet metal fabrication, dimensional inspection, through any necessary secondary operations; and finally, to the final quality assurance of the finished part. A Production Controller or Industrial Specialist determines what resources are available for the fabrication or assembly task and continues to expedite this process, as outlined above, using the appropriate resources. The available resources consist of in-house facilities and approximately 35 local small businesses. The Fabrication Management staff assures that the customer's job is processed in a timely, streamlined manner.

4.5 Quality Assurance Documentation

As mentioned in the previous section, the Fabrication Management Section provides complete traceability of paperwork to certify the quality of the hardware for space flight use. The GSFC Certification Log is a written record of every step in the processing of a part. This usually begins with flight material certification and includes documentation of the machining process, dimensional inspection, chemical surface treatment, installation of inserts, and final quality assurance release of the part. This process is not only documented on paper, but is also in a computer database called the Fabrication Engineering Management System (FEMS) in which the customer can view Certification Log status on line in real time.

4.6 Discipline Engineering Support

Codes 751 and 752 also provide discipline manufacturing engineering support in the areas of computer aided manufacturing, chemistry, advanced composite materials, and mechanical engineering. These professionals are available to provide additional technical expertise to the flight projects and instrument development groups.

4.7 Centralized Flight Fastener Inventory

The ESD Fabrication Management Section maintains an inventory of flight qualified bolts, screws, nuts, washers, rivets, etc., for use by the in-house fabrication and assembly organizations. The inventory has the potential to minimize assembly schedule delays due to the long procurement lead times for many fasteners. The inventory is maintained and controlled by the Fabrication Management Section; Figure 1 lists the point of contact for further information.

5.0 Documentation Requirements

5.1 Overview

As specified in Goddard Management Instruction, GMI 8500.1C under Fabrication and Assembly Services, there are several items of documentation required to use the fabrication services in Building 5. This paperwork includes a Form 8-11, "Work Request" and six copies of folded drawings and specifications.

5.2 Work Request

The Work Request is GSFC Form 8-11 (See Figure 2). All four copies of this form should be submitted to the Fabrication Management Section, Code 752.3. The guidelines listed below should be followed when submitting a Work Request:

A. Each Work Request should be submitted with an appropriate procurement control number, labor job order number, and funding job order number.

B. The Work Request must be signed by a person authorized to sign a Procurement Request of the same monetary value.

C. The requestor should use a unique descriptive title for the work to be performed.

D. Please allow a reasonable amount of time to complete the work when specifying the customer need date.

E. Please assume that the work is for space flight use if there is any doubt. It doesn't cost any more time to certify materials and processes. However, it may be impossible to certify and collect required documentation after the fact.

F. It is also helpful if the customer provides the Fabrication Management Section with the name of an alternate knowledgeable person to contact if problems occur during the processing of the job.

5.3 Complete Drawing Package

The Fabrication Management Section requires six copies of the engineering drawings along with six copies of any specifications that are enumerated, particularly if they are Non-Federal or Non-Government specifications. All drawings submitted to the Fabrication Management Office must be checked and signed by someone other than the designer. The checker should be extremely familiar with ANSI Y14.5, "Dimensioning And Tolerancing." Reproductions should be checked for quality and readability, especially when they are enlarged from microfiche or "A"-sized drawings.

6.0 Funding Requirements

There must be funding available for all fabrication and assembly work before a shop order can be generated by the Fabrication Management Section from a valid Work Request. Without a Work Request, work cannot begin. It is therefore imperative that a valid funded fiscal job order number (FJON) be in the GSFC Financial Management Division Computer. The FJON is a 12-digit number that must begin with the customer's Code and end with the last two digits of -62.

The operations and materials costs are charged back to the FJON on a monthly basis. This is documented in the Financial Management Division Report and is available from the Fabrication Management Office and the GSFC Project Resource Analyst. This report gives estimates of schedule

Figure 2. Work Request Form (Front)

GODDARD SPACE FLIGHT CENTER
WORK REQUEST

1. USER REQUEST DATE		CAT	SHOP NUMBER		MOD
					PLANNER
2. SHORT TITLE OF WORK					LEAD SHOP
3. FISCAL JOB ORDER NUMBER		4. LABOR JOB ORDER NUMBER		5. DESIRED COMPL	
6. PROCUREMENT CONTROL NUMBER Ø — —	7. APPROP. FY TYPE	8. S. FLIGHT YES/NO	9A. MAT. CERT. YES/NO	B. INSP YES/NO	C. DYE PEN YES/NO
10. REQUESTER'S LAST NAME, FI	11. CODE	12. PHONE	13. BLD	14. ROOM	DATE RECEIVED
15. AUTHORIZED PERSON'S SIGNATURE		ESTIMATED HOURS	ESTIMATED COST		EST. COMP. DATE
16. COMPLETE DESCRIPTION (ATTACH SKETCHES ON SEPARATE SHEETS)					

GSFC 8-11 (6/88) ORIGINAL COPY

Work Request Form (Back)

GODDARD SPACE FLIGHT CENTER WORK REQUEST FORM (GSFC 8-1 1)
INSTRUCTIONS TO ORIGINATOR

Originators are responsible for completing Items # 1-16. (Do not write in shaded areas.) Keep Copy No. 4 for your records before submission.

Items:

1. User Request Date — Month/Day/Year request is initiated.
2. Short Title of Work — A clear, descriptive name for parts or assemblies. Be as specific as possible in space provided.
3. Fiscal Job Order Number — Must be a valid 12-digit labor JON beginning with requester organization code and ending with a 62 function code.
4. Labor Job Order Number — A valid 12-digit labor JON designated as such in the current chart of accounts, with a 62 function code.
5. Desired Completion Date — Month/Day/Year.
6. Procurement Control Number — Obtain from project or branch financial analyst.
7. Appropriation Fiscal Year and Type: Valid types are: RD (R&D), CF (C of F), RP (R&PM), TD (T&D).
8. Is work for space flight use?

9A. Is material certification required?
9B. Is mechanical (dimensional) inspection required?
9C. Is dye-penetrant inspection required?
10 – 14. Requester Contact Information.
15. Signature of authorized person.
16. Complete description of work to be performed, quantities required, drawing numbers and other references, special instructions, etc. Attach drawings as required

and cost together with detailed costing for each shop number that is generated from the Work Request. A summary costing for each FJON is also given.

7.0 Special Considerations

7.1 Design Considerations

As mentioned previously, customers may obtain technical help in the area of designing for manufacturability from three different sources: The staff in the Fabrication Management Section, the section heads of the Machining Technology and Fabrication Engineering Branches, and the videotapes entitled, "Tutorials For Design Engineers", available from the GSFC Learning Center. Remember the following points:

A. Carefully evaluate designs and tolerances, and be as generous as possible. Producing tight tolerances, fine surface finishes, and small corner radii are generally expensive and time consuming.

B. Review notes and specifications to ensure that they apply.

C. Use Military Specifications, Federal Standards and National Aerospace Standards whenever possible. Avoid Proprietary Specifications.

D. Avoid multiple finishes (anodize, iridite, electroplates) on a component. Masking and multiple processes are slow, expensive, and risky.

7.2 Long Lead Fasteners

Fasteners are very often the longest lead items in a space flight assembly due to requirements for high strength materials and special lubricants. Code 750 is developing an inventory of commonly used fasteners (bolts, screws, nuts, washers, rivets, etc.). These fasteners are fully qualified to the GSFC S-313-100 Fastener Integrity Plan. Code 750 is making every effort to stock the most commonly used fasteners. However, if a customer needs a specialty item to be used in a fabrication or assembly task, Code 750 can order those items. Please provide fastener lists as soon as they are known. This should occur before detailed drawings are completed and submitted to the Fabrication Management Section.

7.3 Long Lead Materials

Code 750 stocks most commonly used materials including many aluminum alloys of different tempers and thicknesses, a large stock of 6Al4V titanium, many stainless steel and steel alloys, and a wide range of plastics. Again, if a customer needs special materials for a job that will be submitted to Code 750, please submit those lists to the Fabrication Management Section as soon as possible so that we have sufficient time to order and receive the materials.

7.4 Suggestions For Better Fabrication Service

A. Use the technical expertise of the Fabrication Management Section and shop personnel. Include the Production Controller or Industrial Specialist as part of your team early in the process.

B. Submit all of your Work Requests directly to the Fabrication Management Section. The shop section heads and technicians are not permitted to begin work without authority from the Fabrication Management Section.

C. Submit as much information about the task as possible at the start.

D. Specify reasonable deadlines, and expect some administrative lead time to process your work.

E. Use commonly available materials and fasteners whenever possible. Use Military, Federal, MS, NAS or other standard specifications whenever possible.

F. Understand the impact of very tight tolerances and multiple chemical surface finishes. Both of these drastically increase cost and time requirements.

8.0 Customer Feedback

To better serve our customers, Codes 751 and 752 send out a Fabrication Services Customer Survey at the completion of each task as defined by the statement of work on the Work Request. Please let us know how we are doing and what we can do to improve.

3.0 ENVIRONMENTAL TEST ENGINEERING AND INTEGRATION

INTRODUCTION

The Environmental Test Engineering And Integration Branch provides facilities, instrumentation, data analysis, and testing of spacecraft, instruments, and components for environments induced by ground handling, launch, powered and orbital flight. The Branch conducts mass property, magnetic, and electromagnetic compatibility measurements that are required for determining spacecraft performance. The Branch electrically and mechanically integrates flight hardware ranging from subassemblies to fully-configured flight spacecraft. Also, the Branch has responsibility for the design, fabrication, and installation of multi-layer thermal insulation for spacecraft and instruments.

3.1 CAPABILITIES

The Environmental Test Engineering And Integration Branch's function includes five main technological testing and integration disciplines as follows:

Structural Dynamics:	Vibration Acceleration Acoustic Mechanical and static load Mass properties and spin balance Modal survey Data analysis (flight and ground data)
Electromagnetics:	Electromagnetic compatibility Magnetic
Thermal Control:	Fabrication and installation of thermal blankets
Mechanical Integration:	Maintenance and operation of cleanrooms Electrical and mechanical integration Handling of spacecraft Functional checks of spacecraft hardware Field support at launch sites and remote facilities
Space Simulation:	Solar simulation Thermal/vacuum Leak detection Molecular contamination monitoring Temperature/humidity control

Details of facilities used by Branch personnel, and their capabilities are described in the following sections. Most facilities are equipped with state-of-the-art computer network capabilities. Connections for Ethernet (10BASE2 and 10BASE-T) with access to the INTERNET and Point-to-Point Fiber Optics are available.

3.2 STRUCTURAL DYNAMICS
3.2.1 VIBRATION FACILITY

GENERAL: The Vibration Laboratory provides all necessary services and equipment to perform shock and vibration testing of spacecraft and subsystems. Digital control systems provide sinusoidal, random, and transient waveform control to four separate electrodynamic exciters. Data acquisition systems condition and record accelerometer and strain gage signals. A small machine shop with drill press, milling machine, and band saw is used for simple fixture fabrication.

CONTROL SYSTEM: Digital vibration control systems process from 1 to 4 accelerometer signals and control on the minimum, maximum, rms, or average of the signals. A redundant accelerometer is always connected to an Unholtz-Dickie 123 vibration monitor limiter which has selectable acceleration and displacement limits for overtest protection.

CONTROL SYSTEM SINE & RANDOM PARAMETERS

VIB PARAMETER	SINE	RANDOM
Frequency range	5 Hz to 2 KHz	5 Hz to 2 KHz
Output dynamic range	72 dB	60 dB
Sweep rate, linear	1 to 1,000 Hz/sec	N/A
Sweep rate, log	0 to 8 Octave/min	N/A
Break points per spectrum	up to 32	up to 32
Loss of signal protection	Automatic shut down	Automatic shut down

CONTROL SYSTEM TRANSIENT WAVEFORM PARAMETERS

Pulse types	Half-sine, sawtooth, rectangular, double rectangular, triangular, user-defined
Pulse amplitude	0.1 to 10,000 g (Limited by exciter capability)
Pulse duration	0.5 to 1,000 milliseconds

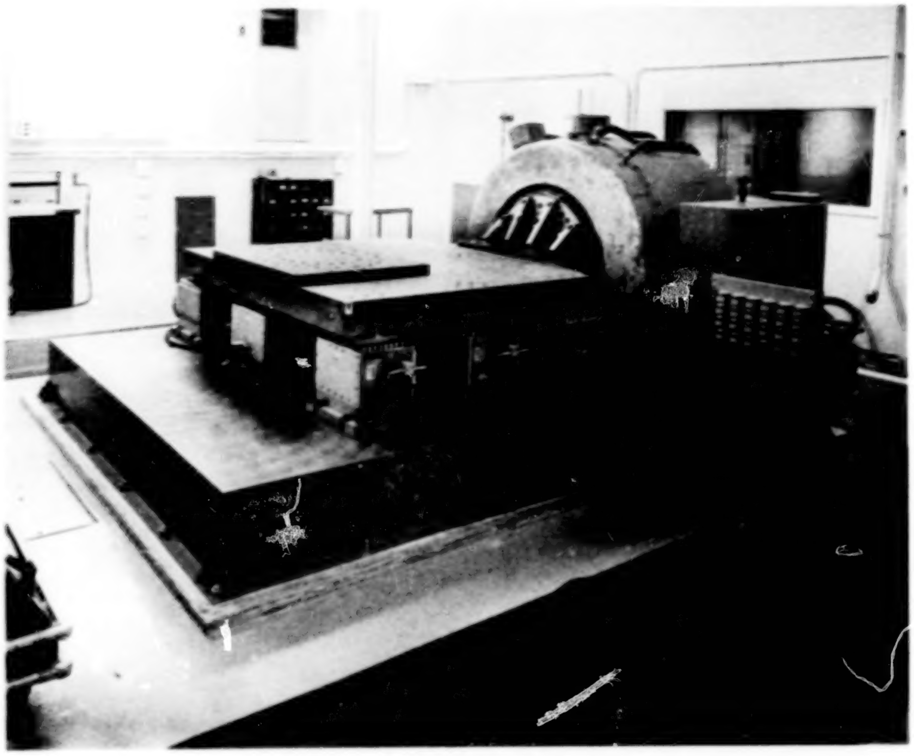
VIBRATION EXCITERS: Ling B-335 (2 each) and MB C-220 (2 each) exciters are located on isolated seismic blocks. Payloads up to 227 Kg (50[illegible]) are tested on the Ling B-335 exciters, and up to 4,082 Kg (9,000 lb) are tested on the MB C-[illegible] exciters.

The Ling B-335 exciters share a common test cell, with one set up for vertical and the other set up for lateral testing. The lateral exciter drives a Team 1830 lateral slip table. An 1,814 Kg (2 ton) monorail crane services both exciters.

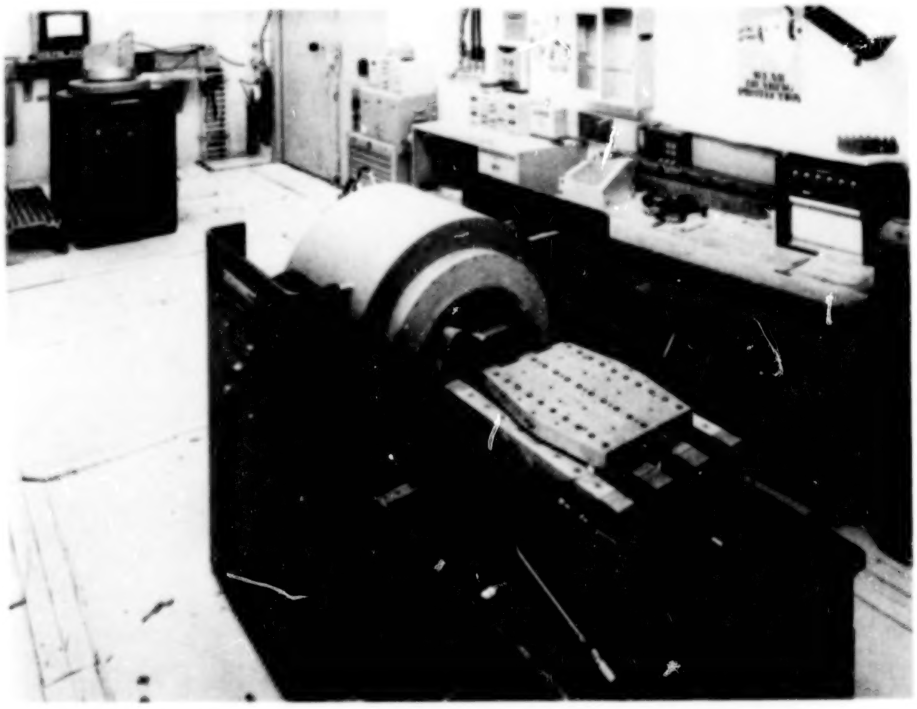
Each MB C-220 exciter is located in its own test cell, serviced by its own 6,804 Kg (7.5 ton) overhead bridge crane.

VIBRATION CONTROL SYSTEM

VIBRATION EXCITER & TEST CELL PARAMETERS		
PARAMETER	**LING B-335**	**MB C-220**
Force rating	Sine vector - 78 K-newton (17,500 lb) Random rms - 53 K-newton (12,000 lb)	Sine vector - 156 K-newton (35,000 lb) Random rms - 110 K-newton (24,700 lb)
Exciter power amplifier	A single Ling 8048 PA (72 KVA) drives either exciter	One of two separate Ling 8096 PAs (192 KVA) drives either exciter via a Ling automatic switching system
Displacement limit	2.5cm (1.0") Double amplitude	2.5cm (1.0") Double amplitude
Velocity limit	178cm/second (70in/sec)	178cm/second (70in/sec)
Frequency range	5 Hz to 2 KHz	5 Hz to 2 KHz
Payload vertical centering	Centers up to 907 Kg (2,000 lb) via pneumatic system	Centers up to 2,268 Kg (5,000 lb) via integral electrical system Centers up to 4,536 Kg (10,000 lb) via auxiliary airstroke actuator suspension system
Lateral slip table	Team 1830 lateral slip table 74cm L x 51cm W (29" x 20") connected to the lateral exciter	Exciter #1: 183cm L x 152cm W (72" x 60") slip plate on 7 each Team bearings Exciter #2: 178cm L x 168cm W (70" x 66") slip plate on 9 each Team bearings
Test cell dimensions	11.3m L x 4.6m W x 4.9m H (37' x 15' x 16')	8.8m L x 8.2m W x 15.5m H (29' x 27' x 51')
Crane capacity	1,814 Kg (2 ton) monorail crane	6,804 Kg (7.5 ton) bridge crane
Access doors	2.5m W x 4.9m H (8'3" x 16')	Upper door: 4.9m W x 9.0m H (16'2" x 29'5") Lower door: 2.5m W x 4.9m H (8'3" x 16')
Cleanroom capability (when required)	Payload can be bagged in special plastic with a purge system.	Payload can be bagged in special plastic with a purge system. Exciter #1 test cell can be operated as a class 10,000 cleanroom, but requires funding and extra time to clean and certify it before a test.



MB C-220 EXCITER #2



LING B-335 EXCITERS

3.2.2 DATA ACQUISITION FACILITY

DESCRIPTION: The data acquisition systems provide signal conditioning and recording capabilities for transducers used in vibration, acoustic, pyroshock, and other types of tests. There is a permanent system located near the vibration and acoustic facilities and a portable system that may be used wherever needed. A network of coaxial cables connects the permanent system to the vibration test cells, the acoustic reverberation chamber, the vibration and acoustic control rooms, and the Data Reduction Laboratory.

PERMANENT SYSTEM: The permanent data acquisition system contains the following:

<u>Recording Systems:</u>	
Honeywell 101 FM tape recorder:	14 channels
FM multiplex system with Honeywell 101 tape recorder:	84 channels
<u>Signal Conditioning Systems:</u>	
Endevco computer controlled charge amplifier system:	72 channels
Unholtz-Dickie D22 charge amplifier system:	12 channels

<u>Signal Monitoring:</u>
Oscilloscopes, digital voltmeters, frequency counters

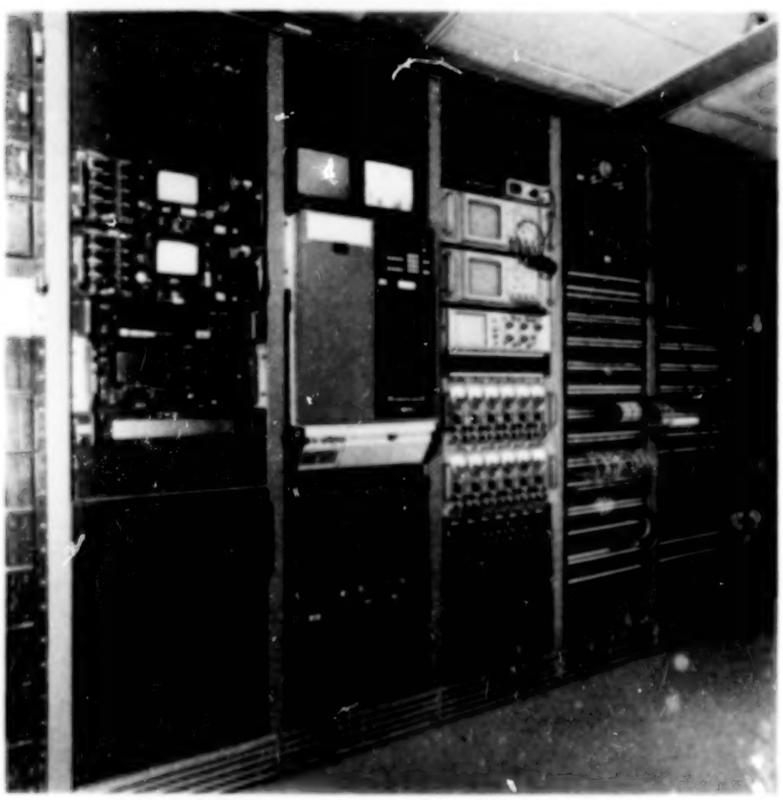
PORTABLE SYSTEM: The portable data acquisition system contains the following:

<u>Recording System:</u>	
FM multiplex system with Honeywell 96 tape recorder:	90 channels
<u>Signal Conditioning Systems:</u>	
Endevco computer controlled charge amplifier system:	72 channels
Unholtz-Dickie D11 charge amplifier system:	30 channels

<u>Signal Monitoring:</u>
Oscilloscopes, digital voltmeters

AUXILIARY SYSTEMS: A set of 12 Unholtz-Dickie D22 charge amplifiers is available for remote signal conditioning uses. A Vishay 2120 strain gage signal conditioning system with 30 input channels is mounted on a portable cart for use where needed.

PORTABLE ACQUISITION SYSTEM



PERMANENT ACQUISITION SYSTEM

3.2.3 DIGITAL DATA ACQUISITION SYSTEM

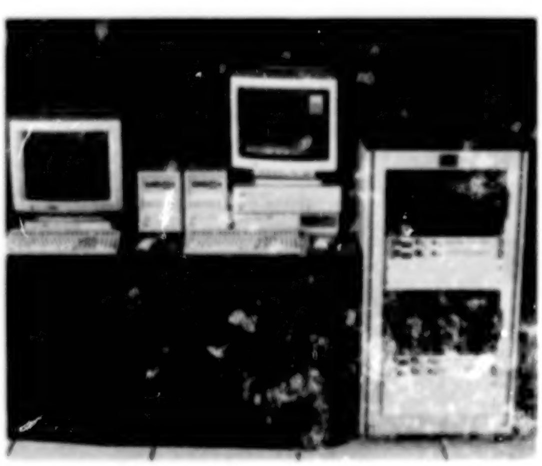
DESCRIPTION: The digital data acquisition system (DDAS) is a high frequency, multichannel dynamic data acquisition system that has been designed specifically to support vibration, acoustic, and modal survey testing. The modular system can be configured to support more than one test at a time. The system has salient features as shown below:

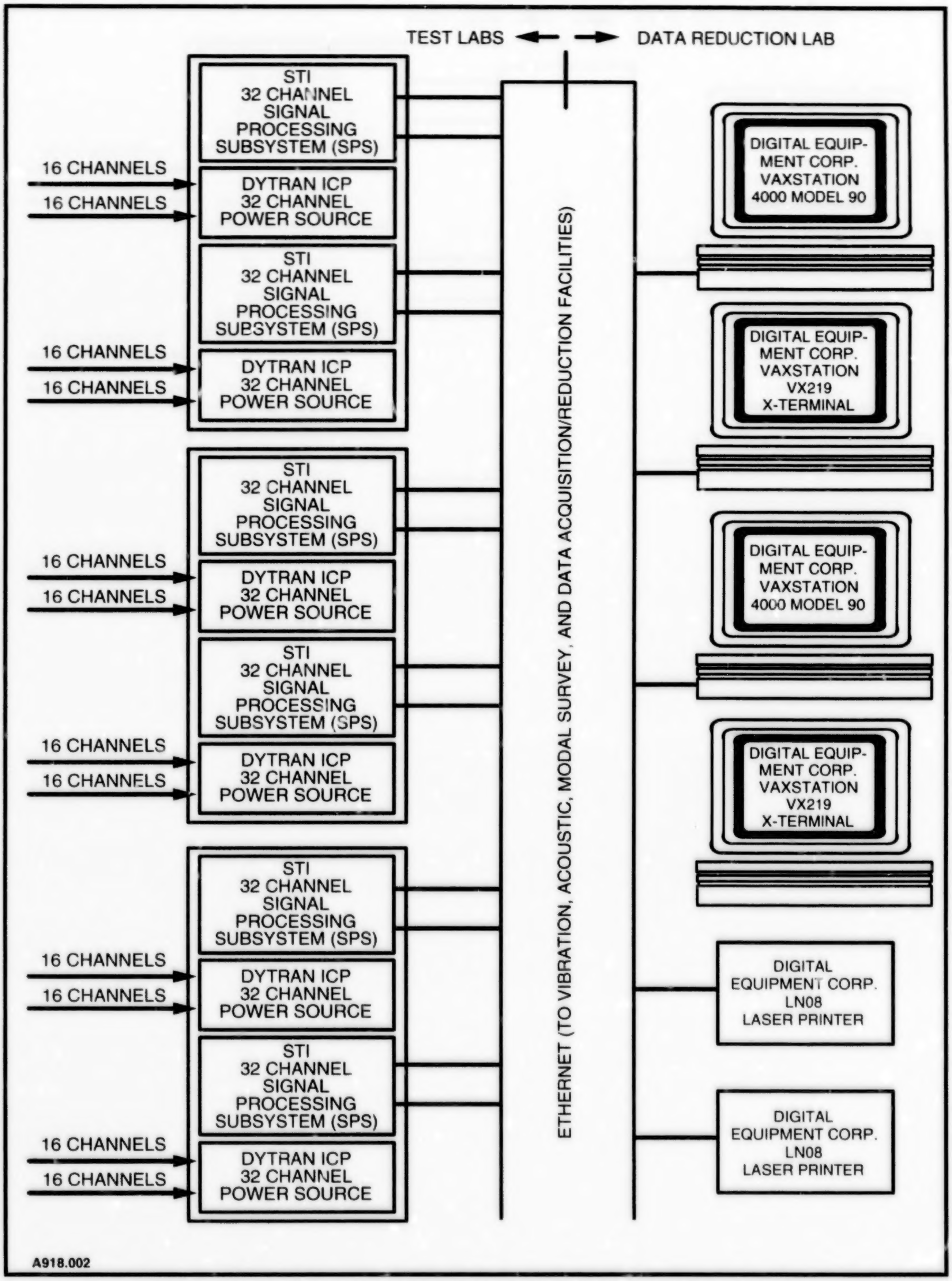
- Current system consists of six modules.
- Each module provides two independent, 16-channel data acquisition systems (32 channels/module), consisting of signal conditioning, filtering, analog to digital converter, and throughput hard disk for data storage.
- Each input channel can accommodate either voltage or integrated circuit piezoelectric (ICP) inputs.
- Each module is controlled remotely by a workstation via ETHERNET. Commands are transmitted to the individual modules from the workstation using TCP/IP networking protocol.
- Data acquisition can be initiated either by command or automatically. Once data acquisition is initiated, the module is capable of operating independently of the workstation, acquiring data until the desired amount of data is collected.
- During data acquisition, up to 16 channels of real-time data may be transmitted to the workstation or to an X-terminal for display.
- After acquisition, data may be processed locally at the module level using command files from the workstation, and the processed results can be transferred to the workstation for display, hard copy, or storage.
- Raw test data may also be transmitted to the workstation for additional processing or archiving. Off-line archiving of data is accomplished by rewritable optical disks.

PARAMETERS:

Module acquisition parameters:

	32 channels at 8,192 samples/second	16 channels at 16,384 samples/second
	8 channels at 32,768 samples/second	4 channels at 51,200 samples/second
	4 channels at 65,536 samples/second (10 seconds)	
Amplitude:	± 5 volts full scale	
Data storage:	15 minutes of data at the maximum sample rates shown above	





DIGITAL DATA ACQUISITION SYSTEM BLOCK DIAGRAM

3.2.4 DATA REDUCTION LABORATORY

DESCRIPTION: The Data Reduction Laboratory digitizes analog signals and analyzes the data to produce plots in a useable form. In addition to standard analyses, customized analysis procedures can be provided. The data signals may be digitized directly from their source during a test, or played back from previously recorded tapes. The Data Reduction Lab also has a variety of analog display and recording devices for examining time history data directly.

ANALOG DATA PLAYBACK AND RECORDING: The Data Reduction Lab has three Honeywell Model 96 tape recorders that can be configured for FM, FM Multiplex, PCM, or direct playback or recording. These recorders are used to play back data recorded in the Instrumentation Mezzanine during vibration and acoustic tests. These recorders have DC to 10 KHz bandwidth in the FM mode and 300 Hz to 2 MHz in the direct mode. Two Graphtec WR3600 8-channel oscillographs are available for recording analog time history signals. They have a DC to 10 KHz input bandwidth and a 200 mm (7.9")/sec maximum paper speed.

DIGITAL DATA ACQUISITION: The Data Reduction Lab maintains two digital data acquisition systems as shown below:

ZONIC System 7000	48 input channels	16-bit precision	12,500 Hz sample rate/channel
GenRad 2515 System	16 input channels	12-bit precision	32,768 Hz sample rate/channel

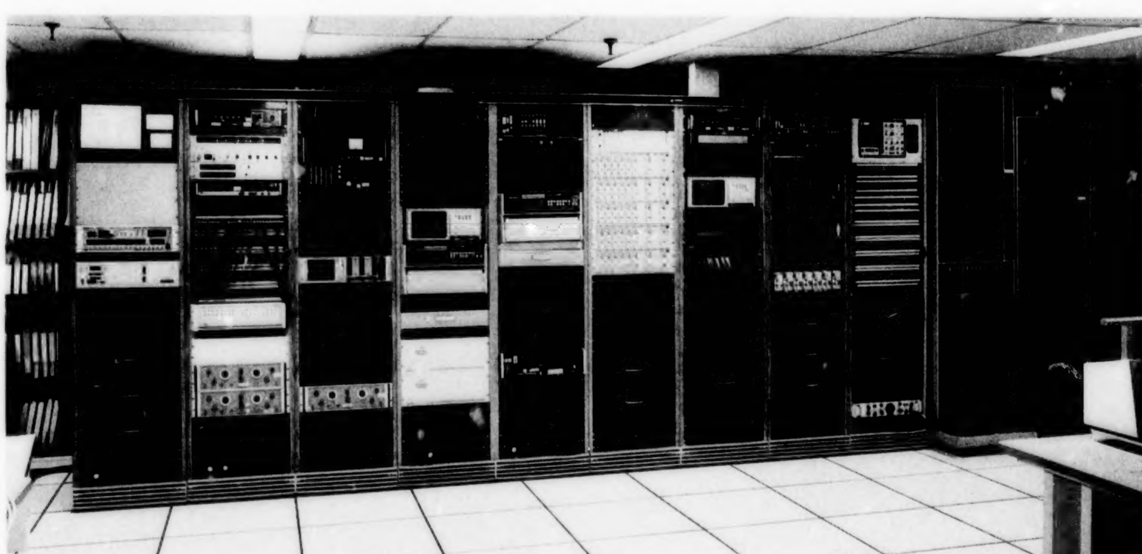
A new system with 192 input channels will be implemented in 1994. A PCM decoding system is also available.

DATA ANALYSIS: Data analysis is performed on a MicroVAX 3500 computer. Data is transferred from the acquisition systems using Ethernet. SDRC IDEAS Test Data Analysis Software (TDAS) is used for most data processing. Custom written software is used for swept sine data analysis. MATLAB software is also available for data analysis and manipulation. There are several language compilers on the MicroVAX that may be used for writing custom applications and utilities.

DATA COMMUNICATION: Data is communicated among the systems in the Data Reduction Lab using Ethernet. The local lab network is connected to the GSFC center-wide network, giving it access to virtually any computer system in the world via Internet. The MicroVAX 3500 is also connected to the GSFC Rolm phone system with a modem bank. This serial communication is available at speeds up to 9600 bits per second. Data may also be communicated in a variety of magnetic formats including DEC TK70 and TK50 tapes, 9-track 1600 bpi tapes (VMS format), and MSDOS or Macintosh diskettes.

ZONIC SYSTEM 7000

GENRAD 2515 SYSTEM



DATA REDUCTION LAB CONSOLE

3.2.5 TRANSDUCER CALIBRATION LABORATORY

DESCRIPTION: This laboratory calibrates piezoelectric, piezoresistive, servo, and strain gage type accelerometers. It contains an Unholtz-Dickie calibration control system with a 1.33 K-newton (300 lb) force capacity exciter, and a Gyrex compound centrifuge.

MODE OF OPERATION:

U-D Calibration System: Transfer standard reference accelerometers are calibrated by the National Institute of Standards and Technology (NIST) annually. The transfer standard is used to determine the sensitivity of the U-D exciter reference accelerometer. Universal fixtures are used to mount unknown accelerometers on the exciter in a back to back configuration with the reference accelerometer. Automatic plots of the unknown accelerometer sensitivity versus frequency are produced by the calibration system.

Gyrex Compound Centrifuge: Servo-type, DC-responsive accelerometers are calibrated on the U-D system, and then used to cross check centrifuge acceleration parameters. Absolute g level is determined by measuring the radius to the center of gravity of the unknown transducer and using a digital frequency counter to adjust the centrifuge RPM levels to calculated values. For low frequency (1 Hz to 10 Hz) calibrations, the accelerometer is mounted on the compound rotating table.

PARAMETERS:

Parameter	U-D Calibration System	Gyrex Centrifuge
Acceleration:	up to 75g	up to 80g
Frequency range:	5 Hz to 5 KHz	0 to 10 Hz
Displacement/radius:	1.78cm (0.7") double amplitude	20cm to 28cm (8" to 11")
Calibration accuracy:	± 3% overall system	± 5% overall system
Transducer size/weight:	up to 15cm (6") cube/0.9 Kg (2 lb)	up to 8cm (3") cube/2.3 Kg (5 lb)

DATA ACQUISITION: For both systems, one transducer at a time is calibrated. Multiple-axis transducers are calibrated one axis at a time. Digital voltmeters, X-Y plotters, and oscilloscopes display the transducer output signals. Cables interconnect the Transducer Calibration Lab to the Data Reduction Lab to facilitate special analysis techniques.

GYREX COMPOUND CENTRIFUGE

UNHOLTZ-DICKIE CALIBRATION SYSTEM

3.2.6 ACOUSTIC TEST FACILITY

DESCRIPTION: The Acoustic Test Facility tests various sized scientific satellites, subsystems, and components. It consists of the reverberation chamber, acoustic horns, noise generators, control console, and data handling system. The facility can be operated as a clean room (Class 100,000) once the payload access doors are closed and the facility is cleaned. An anteroom is used for changing into clean garments before entering the facility through the personnel door.

MODE OF OPERATION: The sound pressure level within the chamber is adjusted to the required spectrum. Small and medium sized payloads are suspended on the crane hook at the center of the chamber. Larger payloads are mounted on carts or fixtures. Four to six control microphones are placed around the payload a minimum of 0.3m (1.0') away.

Acoustic energy is generated by modulating the flow of GN_2 through the generators attached to the horns. A fresh air, forced ventilation system stabilizes the chamber pressure during operation of the facility and purges the chamber of GN_2 for safe entry after the test.

PARAMETERS:

Generators (3):	3-10KW, electro-pneumatic
Horns (3):	25 Hz exponential, 50 Hz hypex, 75 Hz exponential
Maximum SPL:	150 dB overall sound pressure level
Frequency range:	25 Hz to 10 KHz

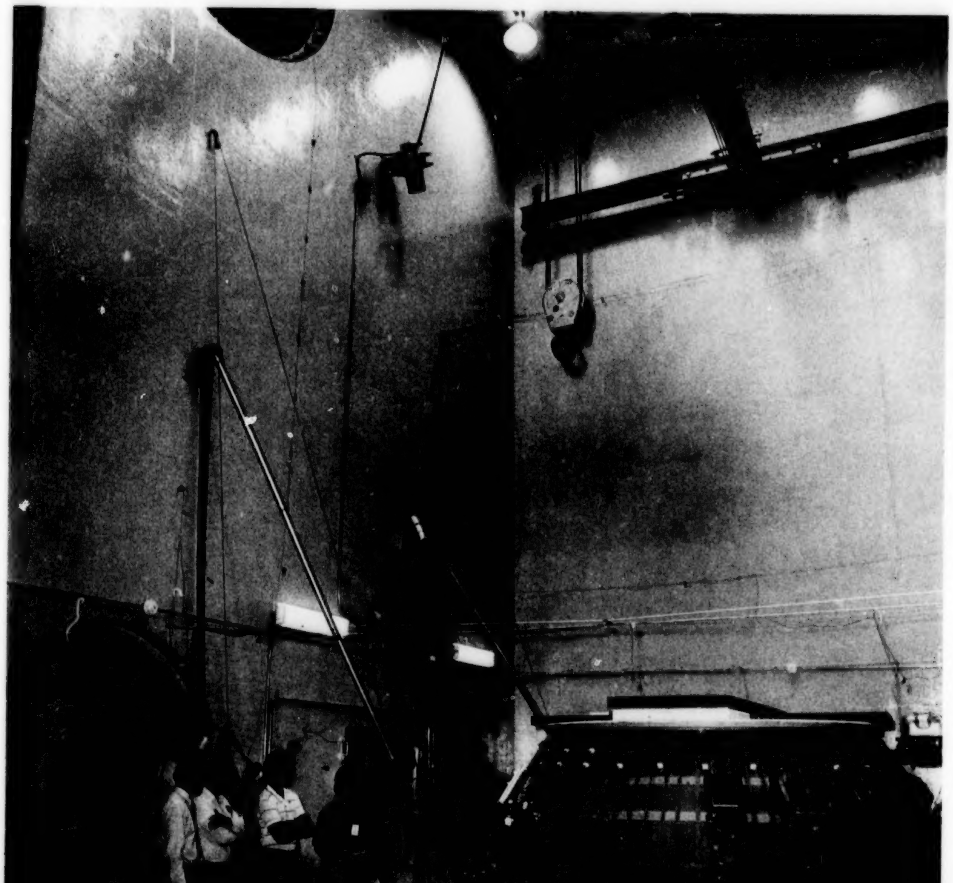
PHYSICAL CHARACTERISTICS:

Interior:	10.0m L x 8.2m W x 12.8m H (33' x 27' x 42')
Payload access:	4.55m W x 9.14m H (14'11" x 30')
Personnel door:	0.91m W x 1.98m H (3' x 6'6")
Crane capacity:	6,804 Kg (7.5 ton)

INTEGRAL INSTRUMENTATION: The PC-based Digital Acoustic Control System (DACS) precisely controls the spectrum of the sound pressure within the chamber in the real-time mode. The control system includes integral equipment such as control microphones, signal conditioners, real-time analyzer, shaper, power amplifiers, acoustic generators, and horns. The DACS communicates with both the real-time analyzer and programmable shaper, and transfers vital test parameter information between each sampling.

DATA ACQUISITION: Microphone, accelerometer, and strain gage signals may be recorded on either a portable instrumentation system or in the "A" Mezzanine. A one-third octave band analyzer is available for either real-time or post-test data analysis. A CCTV is available for observing and recording the payload during the test.

ACOUSTIC CONTROL SYSTEM



ACOUSTIC TEST CHAMBER

3.2.7 MASS PROPERTIES MEASUREMENT FACILITY (MPMF)

DESCRIPTION: The MPMF is used to measure the weight, center of gravity (CG), moment of inertia (MOI), and product of inertia (POI) of large structural assemblies. Also, the facility can be used to balance payloads statically and dynamically.

MODE OF OPERATION: The basic machine has a 1.22m (4') diameter mounting table. A 3.1m (10') table is also available for large payloads. The machine contains a spherical air bearing that supports the measuring table and the test item. A control console is connected to the MPMF by flexible cables and a GN_2 line. The MPMF is controlled by a portable PC system for conducting the test sequences, collecting data, performing computations, and displaying and storing the results.

A complete set of mass properties requires three separate setup configurations of the payload. This requires special fixturing and a turnover facility or other equipment to handle the payload.

Weight Measurements: The facility is mounted on a Pennsylvania 6600 scale base platform (1.75m L x 1.75m W x 0.1m H; 5.75' x 5.75' x 0.33') which gives an immediate digital readout of the weight of the test specimen, regardless of its mounting position on the facility.

CG Measurements: The static unbalance (CG offset) is determined by detecting the moment created by a CG displaced from the measurement axis of the machine.

MOI Measurements: The MOI is determined by using the facility as an inverted torsional pendulum, and measuring the period of oscillation about the geometrical axis of the machine.

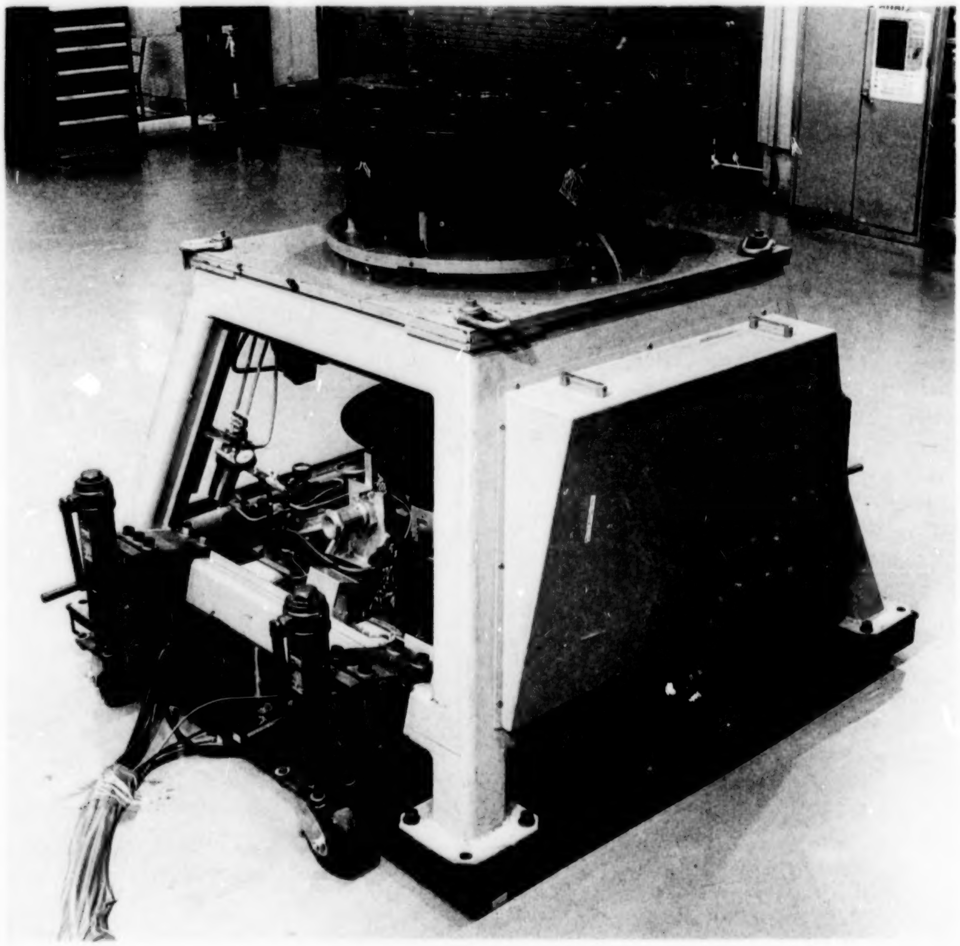
POI Measurement: The POI (dynamic unbalance) is determined by rotating the payload on the MPMF at two different speeds, and measuring the moment.

INTEGRAL INSTRUMENTATION: Instrumentation consists of a control console and a PC computer. These systems measure the unbalance moment, period of oscillation, and table rotational speed. The PC computer is used to conduct the test sequences, collect data, perform computations, and display and store the results.

FACILITY INTEGRATION: The MPMF is portable. It can be operated in cleanrooms, or remotely operated in vacuum chambers at pressures down to 1.33 Kpa (10 torr).

PARAMETERS:

Parameter	Specification
Test weight	up to 4,536 Kg (10,000 lb)
Moment measurement range	up to 3,390 newton-meter (30,000 in-lb)
CG capability	± 0.15cm (0.06") for payload at 0.91m (3') above table and displaced 2.54cm (1") from vertical axis ± 0.3cm (.12") for payload at 3.1m (10') above table and displaced 2.54cm (1") from vertical axis
MOI accuracy	1% of measured MOI
POI accuracy	5% of measured POI
MPMF table speed	0 to 200 RPM
Platform scale capacity	9,072 Kg (20,000 lb)
GN_2 flow rate	$0.17m^3$/minute ($6.0ft^3$/minute) standard



3.2.8 HIGH CAPACITY CENTRIFUGE FACILITY

DESCRIPTION: The High Capacity Centrifuge (HCC) simulates launch and landing loads on spacecraft hardware. Payloads are installed in a cylindrical test chamber at one end, or on a test platform at the other end. The HCC is driven by one or two 0.93 Mw (1250 hp) DC motors operated in conjunction with a motor generator set. Controlled deceleration is possible by using the drive motor(s) in a regenerative mode.

MODE OF OPERATION:

1. Mount payload in test chamber by attaching test article to removable end cap.
2. Pick up and position end cap using loading vehicle, and attach it to test chamber.
3. Use 2,722 Kg (3 ton) crane to position test article on test platform.
4. Use tilt fixtures to orient test article in proper attitude and angle.

PARAMETERS:

	Chamber and Platform
Nominal test radius:	18.3m (60')
Max. payload weight at 30 g:	2,268 Kg (5,000 lb)
Maximum test acceleration:	18.4 g (1 motor) 30.0 g (2 motors)
Maximum speed:	30.0 RPM (1 motor) 38.3 RPM (2 motors)

PHYSICAL CHARACTERISTICS:

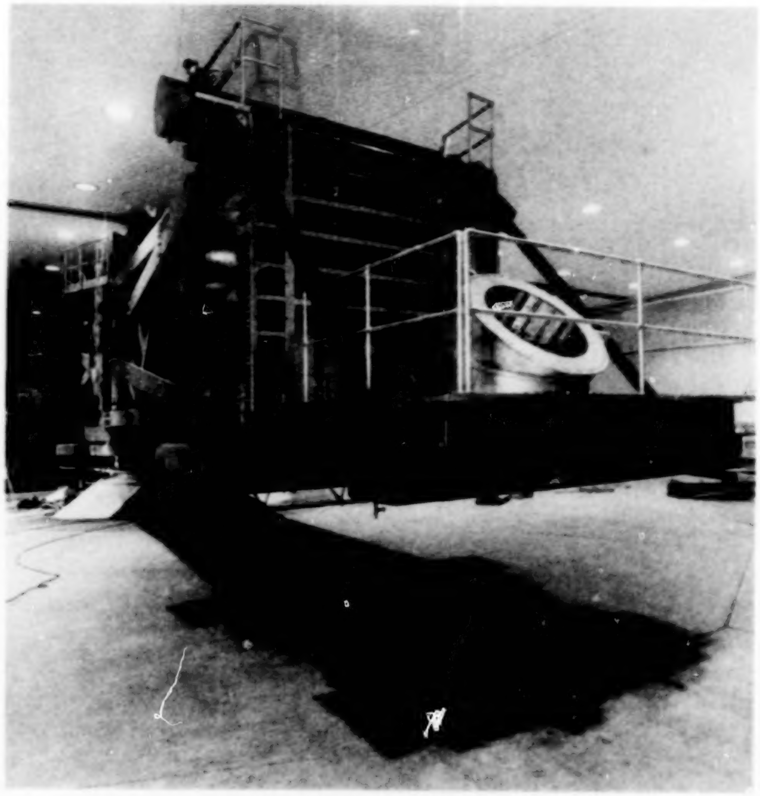
Test chamber size:	3.66m dia x 6.71m (12' x 22')
Platform dimensions:	3.66m x 6.40m (12' x 21')
Platform height (above floor):	1.52m (5')
Crane capacity:	2,722 Kg (3 ton)
Rotunda dimensions:	47.9m dia x 8.23m H (157' x 27')

Slip Rings

Instrumentation/control:	24 (5A) and 986 (1A)
Radio frequency:	6
Power:	30-100A @600V
CCTV system:	2

DATA ACQUISITION: The facility is serviced by the Hewlett-Packard (HP) VXI data acquisition system. Onboard the centrifuge arm, the VXI mainframe unit provides signal conditioning and data acquisition. In the HCC control room, the HP workstation provides test setup, instrumentation test control, data display, and data storage. The system is capable of various combinations of 256 channels of strain, deflection, and acceleration measurements. Also, CCTV and video recorders are provided.

ADDITIONAL NOTES: The change-over from one to two motor operation requires a retuning of the electrical drive circuitry, and a new baseline data run to be performed.



HCC WEIGHT BUCKET TEST PLATFORM

HIGH CAPACITY CENTRIFUGE

3.2.9 UNIVERSAL STATIC TEST FACILITY

DESCRIPTION: The Universal Static Test Facility is a structural steel framework designed for the application of static loads to large shuttle-sized test items and payload handling assemblies.

MODE OF OPERATION: The test item is mounted in the facility using a 31,752 Kg (35 ton) overhead crane servicing the area. Pre-drilled reaction beams facilitate set up and operations. Strain gages and displacement transducers are installed and connected to the Hewlett-Packard (HP) VXI data acquisition system for monitoring. Hydraulic actuators and associated load monitoring devices and load links are installed between the structure and the test item. Loads are applied to the test item via manually-controlled hydraulic actuators. Removable structural members allow for both ease of test item installation and mounting of load application devices.

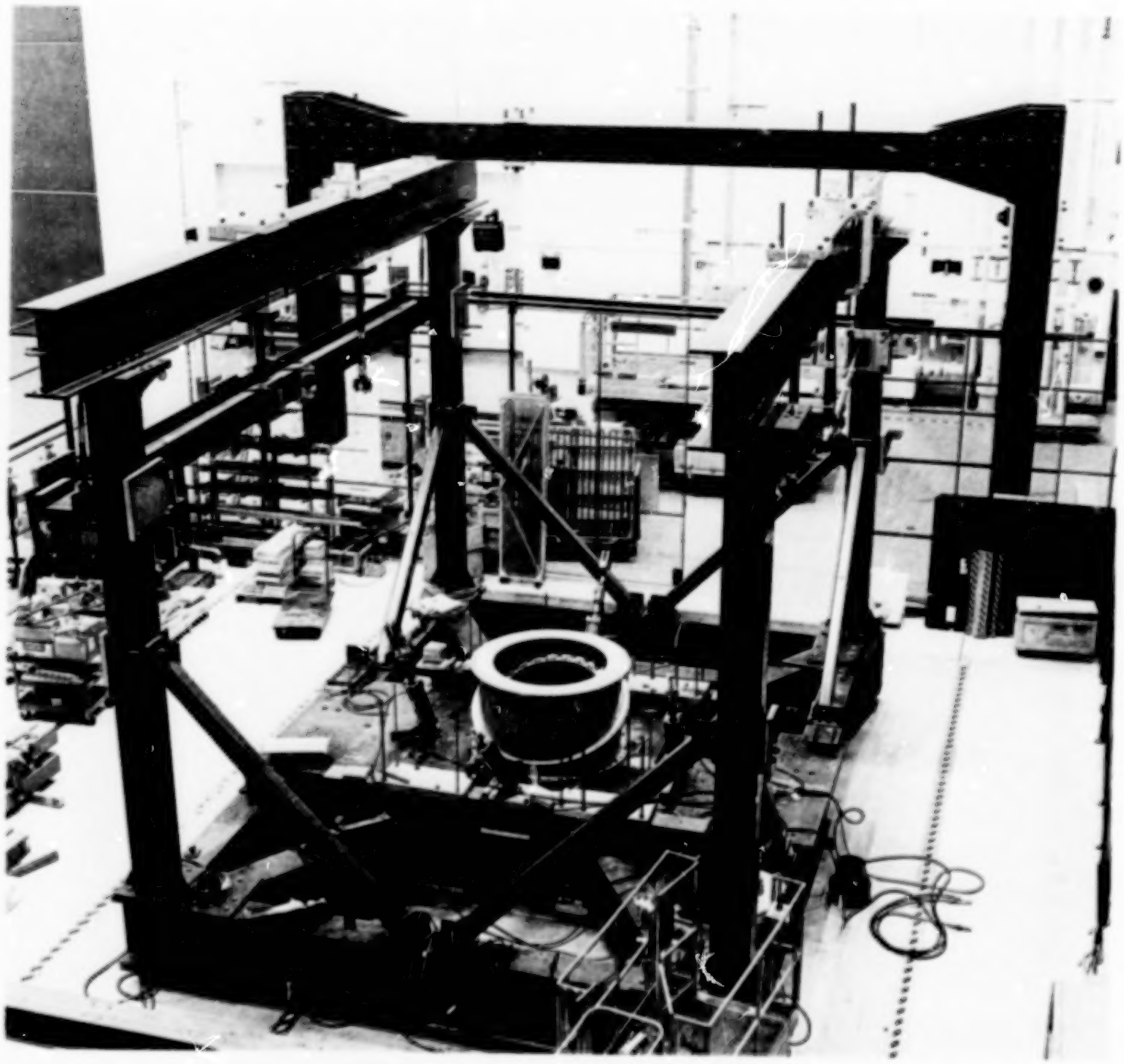
PARAMETERS: The facility is designed for the application of large loads associated with shuttle payloads. With some modification it is capable of loads of 36,288 Kg (80,000 lb). The structure can apply the following simultaneous test loads:

Vertical load:	Up to 11,794 Kg/beam (26,000 lb), 2 beams total
Lateral load:	Up to 18,598 Kg (41,000 lb)

PHYSICAL CHARACTERISTICS:

Internal test envelope:	6.7m L x 4.6m W x 4.6m H (22' x 15' x 15')
Facility weight:	19,958 Kg (44,000 lb)
Crane capacity:	31,752 Kg (35 ton), Building 29 overhead

DATA ACQUISITION: The facility is serviced by the HP VXI data acquisition system. The system is capable of various combinations of 256 channels of strain, deflection, and load measurements.



UNIVERSAL STATIC TEST FACILITY

3.2.10 SMALL STATIC TEST FACILITY

DESCRIPTION: The Small Static Test Facility is a structural test bed, designed for the application of static loads to payload components, sub-assemblies, and associated handling and lifting hardware.

MODE OF OPERATION: A crane or other suitable handling method is used to mount the test item in the facility. Strain gages and displacement transducers are installed and connected to the Hewlett-Packard (HP) VXI data acquisition system for monitoring. Hydraulic actuators and associated load monitoring devices and load links are installed between the structure and the test item. Loads are applied to the test item via manually-controlled hydraulic actuators. Removable structural members allow for both ease of test item installation and mounting of load application devices.

PARAMETERS: With minor modifications, the allowable loads can be increased as test requirements dictate. The structure can apply the following simultaneous test loads:

Vertical load:	Up to 9,072 Kg (20,000 lb)
Lateral load:	Up to 36,288 Kg (80,000 lb)

PHYSICAL CHARACTERISTICS:

Internal test envelope:	2.74m L x 2.74m W x 3.10m H (9' x 9' x 10')
Facility weight:	14,515 Kg (32,000 lb)
Crane capacity:	6,804 Kg (7.5 ton), Building 15 overhead crane

DATA ACQUISITION: The facility is serviced by the HP VXI data acquisition system. The system is capable of various combinations of 256 channels of strain, deflection, and load measurements.

3.2.11 UNIVERSAL LOAD TESTING MACHINES

DESCRIPTION: Two Tinius Olsen universal load testing machines are used for tensile and compressive testing of small specimens, and for calibrating load cell transducers.

MODE OF OPERATION: The test specimen is attached to the crosshead using various types of hardware; for example, clamps, threaded rods, friction grips, eye bolts, and plates. Both tensile and compressive loads can be applied to the specimen, at a controlled rate, via a hydraulic ram (Machine #1) or a motor-driven crosshead (Machine #2).

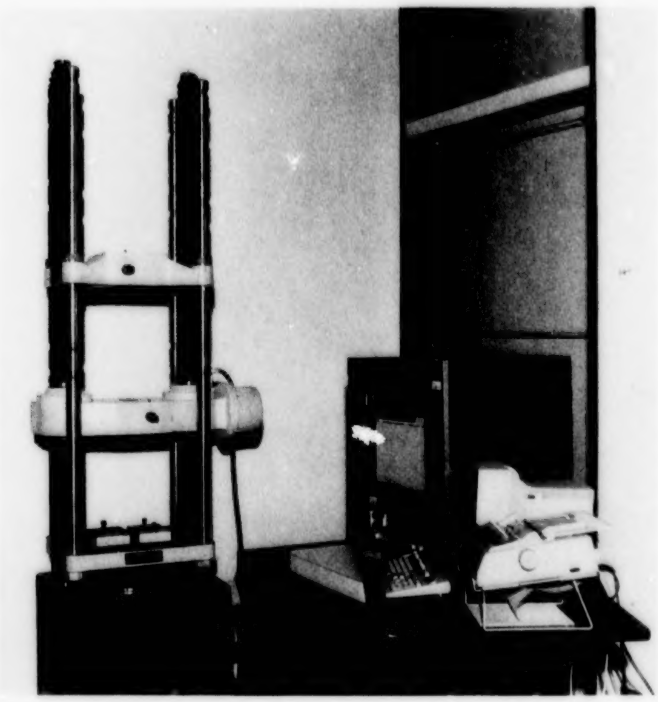
PARAMETERS:

Machine #1 capacity:	0-54,432 Kg (120,000 lb); ± 1% accuracy
Machine #2 capacity:	0-27,216 Kg (60,000 lb); ± 1% accuracy

PHYSICAL CHARACTERISTICS:

Machine #1 test volume:	122cm L x 71cm W x 107cm H (48" x 28" x 42")
Machine #2 test volume:	122cm L x 71cm W x 107cm H (48" x 28" x 42")

INTEGRAL INSTRUMENTATION: Machine #1 has a digital servo control and a digital load readout. Machine #2 has analog control and an analog dial load readout. Both machines can produce plots of deflection or strain versus applied load.



LOAD TESTING MACHINE #1

3.2.12 MODAL SURVEY TEST FACILITY

DESCRIPTION: The Modal Survey Test Facility is used to measure dynamic response characteristics of aerospace structures. The facility consists of a seismic block on which test items are mounted to simulate a fixed boundary condition. A set of stanchions, mounted on the seismic block, provide boundary constraints simulating those of the Shuttle payload bay. The facility is serviced by three bridge cranes, which provide a convenient method of supporting up to four electrodynamic shakers, which are used to apply dynamic forces to the test item. The overhead structure which supports the bridge cranes may be used to suspend test items in a freely-supported test configuration. The facility has been used to apply a step relaxation technique in order to excite low frequency modes with significant energy.

The facility is supported by an instrumentation trailer, located adjacent to the seismic block. The trailer contains signal conditioning and data acquisition systems as well as shaker control systems. The trailer is connected via Ethernet to the Data Reduction Laboratory.

MODE OF OPERATION: The test item is mounted in the facility to simulate the desired constraint conditions. Excitation forces are applied to the test item at one or more driving point locations. Force gages are used to measure the excitation forces, while accelerometers are used to measure the response at selected locations. All of the measurement data is acquired and stored in the time domain format. Post test processing capabilities include frequency response functions, coherence functions, power spectra, etc. Modal parameters are obtained from various curve fitting algorithms which attempt to analytically describe the measured test data.

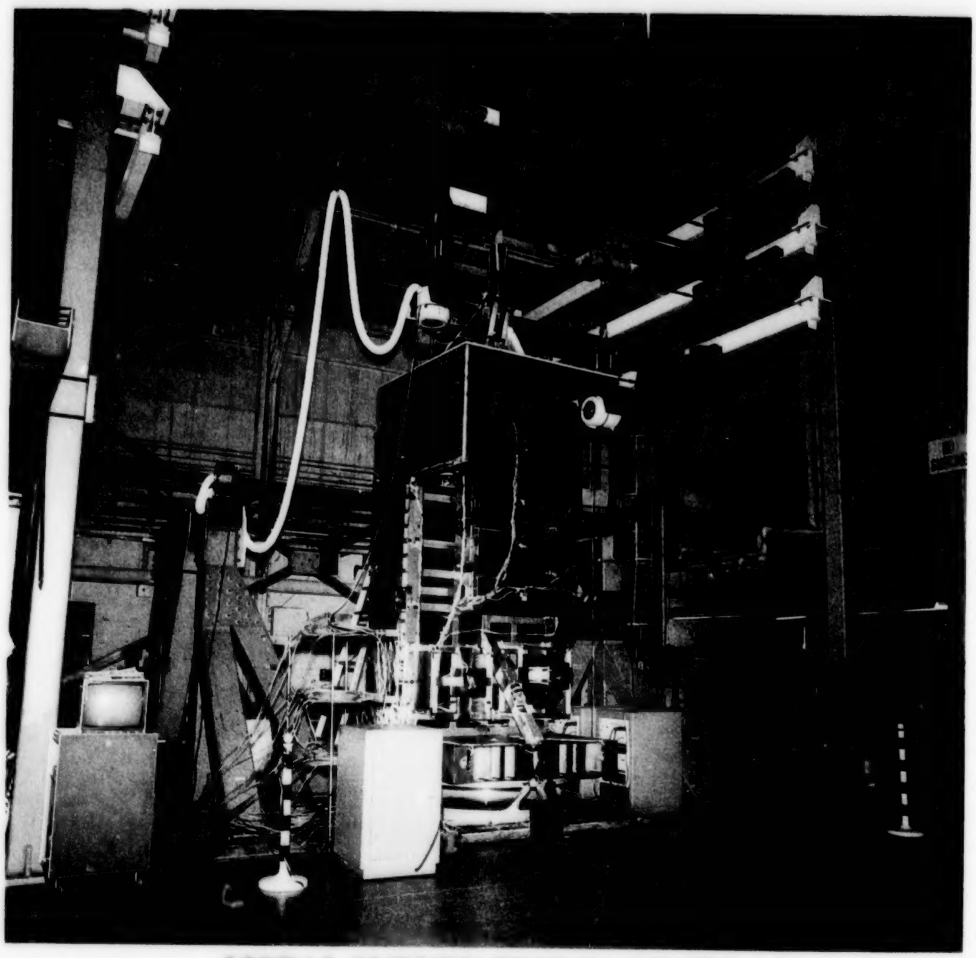
INTEGRAL INSTRUMENTATION: Instrumentation accelerometers, force gages, large and small impact hammers, large and small shakers, seismic accelerometers for floor surveys, signal conditioners, and monitoring oscilloscopes for all data channels.

PARAMETERS:

Excitation type:	random, sinusoidal, impact
Excitation load:	0 to 100 Kg (220 lb)
Frequency range:	2 Hz to 25 KHz
Resolution:	512 data points per frequency range
Shakers:	Force: Small - 23 Kg (50 lb); Large - 100 Kg (220 lb)
Impact hammers:	Force: Small - 0 to 227 Kg (500 lb); Large - 0 to 2,268 Kg (5,000 lb)

DATA ACQUISITION/ANALYSIS: Test data is acquired by digitally sampling the time domain signals from the accelerometers and force transducers. Accelerometer channels are manually switched in groups to acquire all of the required response measurements. Following acquisition, test data is processed using various techniques. One technique uses the fast Fourier transform to compute frequency response functions (FRFs). The FRFs, in turn, are curve fit using algorithms such as complex exponential, poly reference, etc. Other techniques available include random decrement, Ibrahim time domain and Eigenvalue realization algorithm.

MODAL FACILITY CONTROL SYSTEM

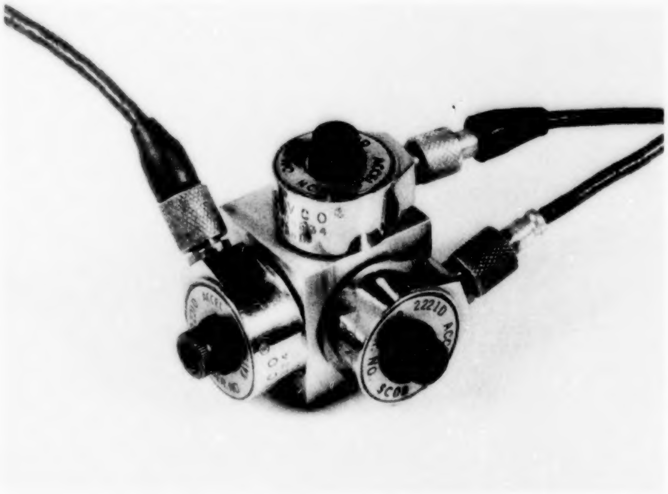


MODAL SURVEY TEST FACILITY

3.2.13 TRANSDUCERS

DESCRIPTION: The Structural Dynamics Branch uses a variety of transducers to measure different environmental parameters. The table below lists typical transducer types along with typical specifications:

Transducer Type	Parameter Measured	Typical Specifications
Accelerometer, piezoelectric	acceleration	0 to 5,000g, 1Hz to 5KHz
Accelerometer, servo/resistive	acceleration	0 to 50g, DC to 1KHz
Displacement (linear variable differential transformer)	linear displacement	0 to 12.7cm (5")
Force gauge	force	0 to 890 newton (200 lb force)
Load cell	load (weight)	0 to 90,720 Kg (200,000 lb)
Microphone	sound pressure level	0 to 175 dB
Proximity sensor	linear displacement	0 to 0.25cm (0.1")
Strain gage	strain	0 to 1270 microns (50,000 microinch)
Torque wrench transducer	torque	0 to 746 newton-meter (550 ft-lb)



ACCELEROMETERS

MICROPHONE

3.3 ELECTROMAGNETIC TEST

3.3.1 ELECTROMAGNETIC COMPATIBILITY TESTING

INTRODUCTION: Two shielded testing facilities are available for conducting electromagnetic compatibility (EMC) tests. These facilities meet electromagnetic performance requirements specified by MIL-STD-462, and support the performance of EMC tests specified by MIL-STD-461 and the GSFC "Goddard Environmental Verification Specification" (GEVS). Both facilities provide very low interior noise level ambient electromagnetic environments and the ability to contain internally-generated, radiated electromagnetic waves. The ambient electromagnetic noise level is verified to be at least 6 dB below test specification limits prior to testing in the facility. Both facilities feature ventilation and other apertures designed as waveguide-below-cutoff to prevent either ingress or egress of electromagnetic waves. All electrical power, communications, and other facility wiring are filtered, and the facility structures are bonded to earth ground, to minimize the introduction of external electromagnetic noise into the facilities. Specifications are identical for both the small and large EMC shielded rooms in the three sections described below: Integral Instrumentation, Data Acquisition, and Auxiliary DC Electrical Power.

INTEGRAL INSTRUMENTATION:

1. Hewlett-Packard (HP) spectrum analyzer-based receiver system (HP 8566B/85865A) mounted on a portable cart for data acquisition, processing, and data reduction. Contains associated electric field and magnetic field antennas and line conduction transducers for testing in the frequency range 20 Hz to 18 GHz. Receiver system is controlled by the HP 85869A EMI measurement software package.

2. Composite electric field and line conduction susceptibility system consisting of signal generators, amplifiers, and transducers for injection and radiation. Frequency range is 30 Hz to 400 MHz for signal injection, and 10 KHz to 18 GHz for signal radiation.

DATA ACQUISITION: All emissions test data is recorded in a swept spectrum analog format on the HP 8566B and reduced to logarithmic versus frequency printout, including a specification limit when applicable, by the HP 85869A EMI measurement software package. The combined HP 8566B and 85869A measurement system is used for radiated and conducted emissions measurements. All susceptibility data is acquired manually during the injection or radiation sweep. During testing, if the experimenter notes frequencies at which the test item is susceptible, these frequencies and threshold levels are recorded manually on data log sheets.

AUXILIARY DC ELECTRICAL POWER:

Two auxiliary power systems are available as shown below:

Low Power DC System- 50 amp maximum, 100 amp-hour portable battery system, 28 VDC, ± 4 VDC

High Power DC System- 100 amp maximum, 600 amp-hour semi-portable battery system, 28 VDC, ±4 VDC; also contains special connections for 24 to 36 VDC in 2-volt increments.

3.3.1.1 SMALL EMC FACILITY

DESCRIPTION: This facility is used for testing console-sized electrical/electronics systems for: 1) **emissions**- radiated and conducted electrical interference levels generated by specific equipment items, and 2) **susceptibility**- the ability of specific equipment items to function properly when subjected to specified levels of radiated and conducted electrical interference to ensure electromagnetic compatibility. The facility consists of three contiguous electromagnetically shielded enclosures: 1) test area, 2) operational control room, and 3) experimenter's area.

MODE OF OPERATION: The test item is transported via the elevator to the EMC enclosure. Large items can be lowered to the facility through a hatch in the floor. After the test article is installed in the test area and secured, the experimenter monitors the performance of the test article from the experimenter's area, while facility personnel operate the EMC receiving and transmitting equipment from the operating control room. The experimenter and facility personnel communicate via closed-circuit communications systems. Portable clean tents with blowers (class 10,000) can be erected for test items that require controlled cleanliness conditions.

PARAMETERS:

Radiated emissions:	20 Hz to 18 GHz
Conducted emissions:	30 Hz to 100 MHz
Radiated susceptibility:	10 KHz to 18 GHz
Conducted susceptibility:	30 Hz to 400 MHz

PHYSICAL CHARACTERISTICS:

Experimenter's area:	4.88m L x 2.44m W x 3.05m H (16' x 8' x 10')	Personnel door:	1.07m W x 1.70m H (3'6" x 5'6")
Control room:	7.32m L x 3.66m W x 3.05m H (24' x 12' x 10')	Personnel door:	1.32m W x 2.11m H (4'4" x 6'11")
Test area room:	5.49m L x 5.08m W x 3.05m H (18' x 16'8" x 10')	Equipment door:	2.13m W x 2.21m H (7' x 7'3")

TEST AREA ANECHOIC CHARACTERISTICS: Ferrite tiles and carbon-impregnated polyurethane wedge blocks mounted on the interior walls of the test area combine to make the facility a broad band anechoic chamber capable of absorbing electromagnetic waves over the frequency range of 10 MHz to 18 GHz. Field measurement accuracy is thereby enhanced compared to shield room facilities that lack the anechoic material, and radiated susceptibility test signals are controlled with improved signal-to-noise ratios.

EMC CONTROL CONSOLE

SMALL EMC SHIELDED ENCLOSURE

3.3.1.2 LARGE EMC FACILITY

DESCRIPTION: This facility is used for testing very large items for radiated and conducted emissions and susceptibility to electromagnetic interference. The facility is a clean room which can maintain class 10,000 cleanliness conditions. The three test equipment locations comprising the facility are: 1) the large shielded enclosure test area located within the Spacecraft Checkout Area (SCA) cleanroom, 2) operational control area located either in the small EMC test facility or adjacent to the south wall of the large shield room, to the right of the magnetic personnel door inside the SCA cleanroom facility, and 3) experimenter's area located outside the large EMC facility, next to the SCA roll up door.

MODE OF OPERATION: Large test items are transported through the SCA roll up door and then through the large EMC room double doors. The transportation method (e.g., air pads, dolly, etc.) is dependent upon the size and weight of the test item. Signal transducers (electromagnetic field antennas and split-core line current transformers) convert the radiated and conducted emissions to proportional analog signal line currents. These currents are conveyed to console-mounted instruments which detect, amplify, and record analog currents as voltages in a 50-ohm system. The EMI measurement software package automates the conversions of the recorded voltages into emission levels that are plotted on graphs and tabulated on data printouts. Electromagnetic fields and line currents/voltages generated for susceptibility measurements are monitored using the same or similar transducers connected to signal sources and monitoring instrumentation.

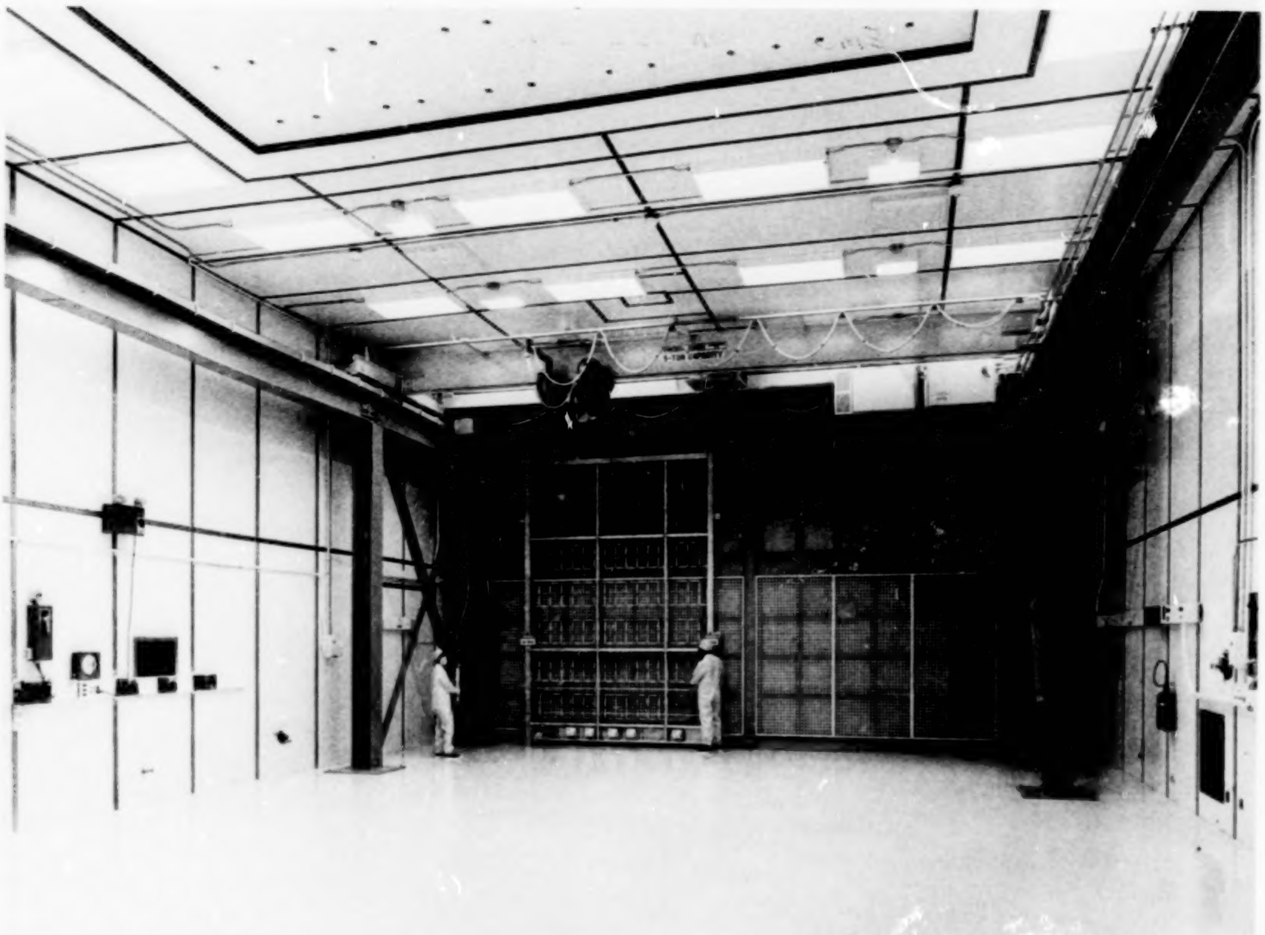
PARAMETERS:

Radiated emissions:	20 Hz to 18 GHz
Conducted emissions:	30 Hz to 100 MHz
Radiated susceptibility:	10 KHz to 18 GHz
Conducted susceptibility:	30 Hz to 400 MHz

PHYSICAL CHARACTERISTICS:

Shielded room size:	19.20m L x 10.67m W x 6.10m H (63' x 35' x 20')
Door size:	6.10m W x 5.79m H (20' x 19')
Crane capacity:	907 Kg (2000 lb), crane to be removed for proposed upgrade

PROPOSED FACILITY UPGRADE (Estimated for 1995):
As part of the proposed upgrade, the existing 907 Kg (2000 lb) bridge crane will be removed, and an interior fiberglass wall structure will be installed. Ferrite tile will be attached to the new wall, designed to provide a minimum of 20 dB absorption of normally-incident electromagnetic waves in the frequency range of 30 MHz to 500 MHz. These walls will reduce the anechoic test area size to 11.58m L x 9.14m W x 6.10m H (38' x 30' x 20'). Two shielded enclosure anterooms will be installed, bonded to the north wall of the existing enclosure, and will provide separately shielded compartments with filtered power and direct access panels to the test area. The larger anteroom (6.71m L x 6.10m W x 3.05m H; 22' x 20' x 10') will house ground support equipment for test items, and the small anteroom will house the EMI test equipment. The large anteroom will be available for sub-assembly testing when tests are not scheduled in the cleanroom facility.



LARGE EMC SHIELDED ENCLOSURE

3.3.2 MAGNETIC TESTING

INTRODUCTION: The remotely located Magnetics Test Site contains two major coil systems, 6.7m (22') and 12.8m (42'), used for magnetic testing of payloads ranging from fully-configured spacecraft down to component level assemblies; and for calibrating torque coils and magnetometers in attitude control systems. Both facilities are 3-axis Braunbek coil systems consisting of 12 coils (4 coils for each of 3 orthogonal axes). Each coil contains windings for Earth's field cancellation, static and dynamic field generation, diurnal variation control, temperature gradient compensation, external gradient compensation, and two sets of spare windings.

Control consoles for both coil systems are located in a separate building apart from the coils. This isolation prevents control equipment magnetic fields from degrading the specified magnetic environment established within the Braunbek coils. For both coils, static and dynamic (0-100 rad/sec) field vectors can be generated along any axis with magnitudes up to 60,000 nT.

3.3.2.1 6.7M (22') COIL MAGNETIC TEST FACILITY

DESCRIPTION: The Magnetic Field Component Test Facility (MFCTF) contains a 6.7m (22') circular coil system. This system provides geomagnetic field cancellation within a 0.9m (3') diameter sphere to levels described below. This coil system is used primarily for testing smaller satellites, performing instrument-level dipole moment measurements, and for calibrating magnetometers and attitude control systems.

MODE OF OPERATION: For a typical magnetometer test, a zero field is established in the center of the coils before the test unit is installed. A reference standard proton magnetometer is then used to calibrate the system. Following this, the test magnetometer is positioned on the platform at the center of the coil and aligned to the coil axes. Finally, static and dynamic fields are generated to establish the linearity, frequency response, zero offset, and alignment characteristics of the magnetometer.

PARAMETERS:

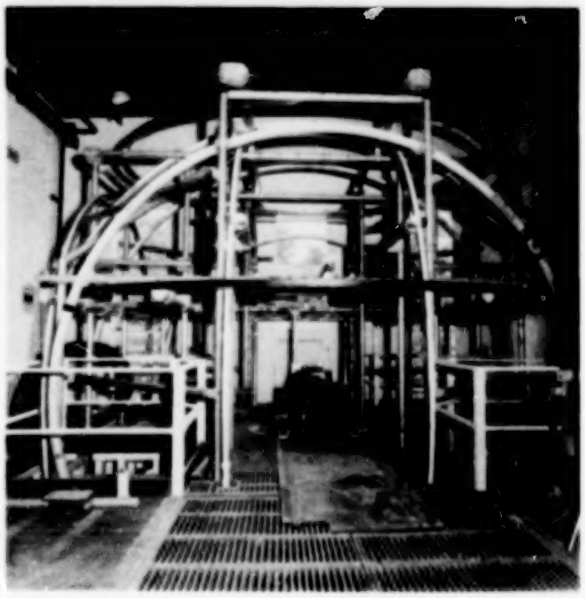
Static Field Capability		Dynamic Field Capability	
Magnitude (each axis)	± 60,000 nanotesla	Magnitude (each axis)	± 60,000 nanotesla
Resolution	± 0.1 nanotesla	Resolution and stability	± 2%
Stability	± 0.5 nanotesla	Frequency	0 to 100 rad/sec
Homogeneity	0.001% (0.91m, 3' dia spherical volume)		

PHYSICAL CHARACTERISTICS:

Coil access opening:	1.52m W x 1.52m H (5' x 5')
Building access opening:	3.05m W x 3.05m H (10' x 10')

INTEGRAL INSTRUMENTATION: The MFCTF is equipped with instrumentation for the calibration and alignment of magnetometers. This instrumentation includes fluxgate and proton magnetometers for zeroing and calibrating. A data acquisition/analysis system is available to acquire the magnetometer data, perform near field analysis, and produce a customer-ready report.

6.7M (22') COIL CONTROL CONSOLE



6.7M (22') COIL MAGNETIC FACILITY

3.3.2.2 12.8M (42') COIL MAGNETIC TEST FACILITY

DESCRIPTION: The Spacecraft Magnetic Test Facility (SMTF) 12.8m (42') coil system is the largest spherical coil system in the world. Its geomagnetic field cancellation system is capable of cancelling the Earth's magnetic field within a 1.83m (6') diameter sphere. The SMTF also has a set of 2.90m (9'6") diameter Helmholtz coils available for perming and deperming spacecraft and 1.22m (4') and 1.83m (6') diameter coils for magnetically cleaning smaller test items.

MODE OF OPERATION:

Magnetic Testing: Zero field is first established in the center of the coil. A reference standard proton magnetometer is used to calibrate the coils. For each measurement sequence, the test item and facility dolly are moved to the center of the coil. As the dolly is rotated 360°, three-component magnetic field data is obtained at increments of 10°. The data are then stored in the computer for immediate display and processing. If the test item exceeds its test limit, compensation magnets can be developed to reduce the dipole moment to acceptable levels.

Spacecraft Magnetometer Calibration: Initial setup is the same as for magnetic testing. The test item is positioned in the center of the coil and aligned with the coil axes. Static and dynamic fields are generated to establish linearity, frequency response, zero offset, and alignment characteristics of the test item. The data system can be used to collect, store, and display test parameters.

PARAMETERS:

Static Field Capability		Dynamic Field Capability	
Magnitude (each axis)	± 60,000 nanotesla	Magnitude (each axis)	± 60,000 nanotesla
Resolution	± 0.1 nanotesla	Resolution and stability	± 2%
Stability	± 0.5 nanotesla	Frequency	0 to 100 rad/sec
Homogeneity	0.001% (1.83m, 6' dia. spherical volume)		

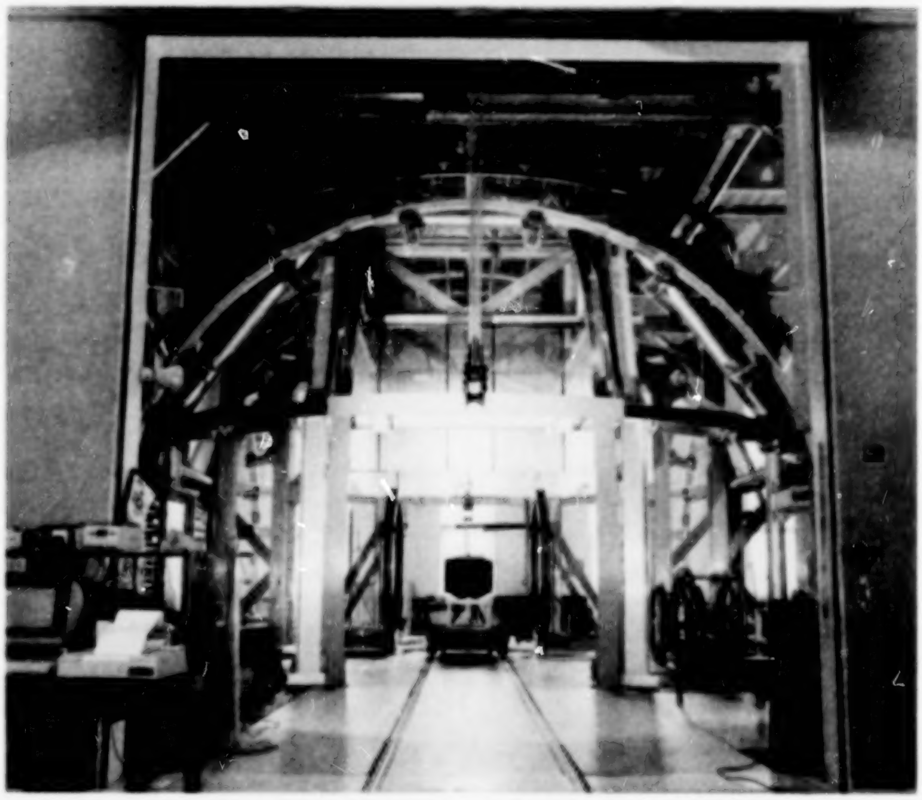
PHYSICAL CHARACTERISTICS:

Coil access opening:	3.05m W x 3.05m H (10' x 10')
Building access opening:	4.27m W x 4.57m H (14' x 15')
Hoists lifting capacities (4):	4,536 Kg (5 ton), 2,722 Kg (3 ton), and two each 2,268 Kg (2.5 ton)

INTEGRAL INSTRUMENTATION: The SMTF is equipped with single and triaxial magnetometers, proton magnetometers, torquemeter, and data collection instrumentation. It contains the three Helmholtz coils described above, with their associated AC and DC power supplies.

DATA ACQUISITION: An array of three state-of-the-art triaxial fluxgate magnetometers is used for magnetic field testing. A field mapping of the test item is performed, the resultant data is input into the facility's "near field analysis" software, and an equivalent dipole moment is calculated. Measurements are taken for various magnetic field conditions which typically include: perm, deperm, induced and stray field (test item powered) measurements.

12.8M (42') COIL CONTROL CONSOLE



12.8M (42') COIL MAGNETIC FACILITY

3.4 THERMAL BLANKETS

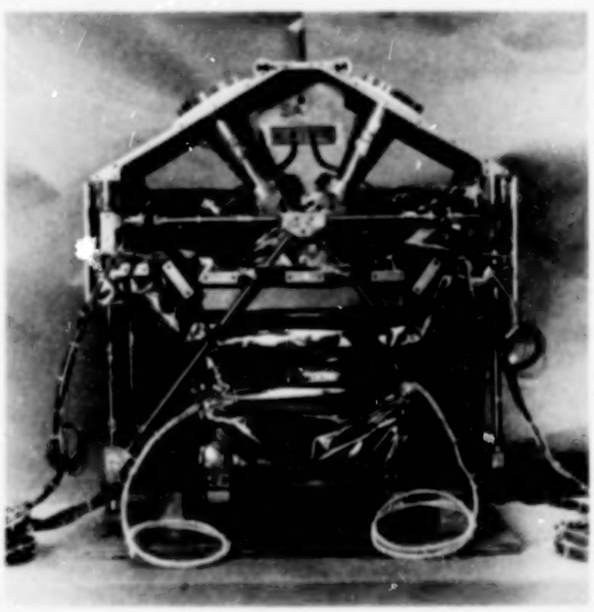
DESCRIPTION: The thermal blanket facility is equipped to provide all aspects of design, layout, fabrication, and installation of multi-layer insulation (MLI) for flight spacecraft, instrumentation, mock-ups, and test fixtures. Consultant services are provided to other NASA centers and aerospace vendors.

MODE OF OPERATION: To meet thermal design requirements, each blanket is custom built. Materials can be baked out in thermal vacuum chambers before fabrication begins. Afterward, the completed blanket can be baked. Metalized and non-metalized thin films (such as Mylar, Kapton and Teflon), dacron netting, special adhesives and tape, fluoroglas fabric (Beta cloth), and a variety of fasteners are stocked and used in the fabrication and installation process. Flight blankets consisting of metalized films are electrically grounded to the spacecraft during installation to avoid build up of static charge. Existing blankets are also modified, refurbished, and repaired.

PHYSICAL CHARACTERISTICS:

- 5 each fabrication tables (one in a controlled, dust-free enclosure)
- Hand held vacuums
- Two medium/heavy weight industrial sewing machines
- Storage for completed MLI and templates

ADDITIONAL NOTES: Bulk blankets generally do not exceed 1.22m x 3.35m (4' x 11'). Installation or construction of MLI can occur directly on hardware in the facility if cleanliness requirements are not stringent and size does not exceed 2.13m L x 1.68m W x 1.98m H (7' x 5.5' x 6.5'). Blanket patterning, modification, and installation often occur in other areas of integration or testing, in contamination-controlled areas, and offsite.



BLANKETS ON PAYLOAD

INSTALLING BLANKETS

3.5 MECHANICAL INTEGRATION

INTRODUCTION

The Division possesses both the facilities and personnel necessary for mechanically integrating spaceflight hardware, including complete spacecraft. This integration effort is provided from the inception of the program through launch and recovery. Normal integration effort is performed in the Division's cleanrooms. However, for non-critical (or non-flight) integration tasks, other areas possessing general lab cleanliness can be used. A more detailed explanation of the Division's integration capabilities follows.

3.5.1 HANDLING OF SPACECRAFT

Typical spacecraft handling tasks include preparation of procedures, use of hydrasets, crane operations, proof testing of lifting devices and handling carts, and fabrication of lifting cables. The Division has extensive facilities, hardware, and trained personnel for both routine and quick reaction handling tasks. Logistics for shipping, receiving, and packaging are also provided at GSFC and other offsite locations.

3.5.2 FABRICATION SUPPORT

Frequently, critical hardware is not available, or unforeseen machining operations need to be performed, so that spacecraft integration tasks can remain on schedule. In those instances where quick reaction is required, trained personnel and facilities are available to modify or fabricate needed hardware.

3.5.3 ASSEMBLY

Both Division and project-supplied hardware is used by the integration group in the assembly of flight systems. Precision assembly tools, measuring instruments, and trained personnel are used to ensure precise alignment and installation of flight hardware. Precision optical transit squares, interferometers, surface tables, inclinometers, electronic levels, height gauges, and helio-precision measuring tools are some of the instruments used for this effort.

3.5.4 FUNCTIONAL CHECKS OF SPACECRAFT MECHANISMS

Division personnel perform weight, moment of inertia, center of gravity, and product of inertia measurements on flight hardware. Functional checks of hinged doors, solar panel deployment mechanisms, payload ejection systems, and boom deployments are routinely conducted in accordance with the designer's and experimenter's specifications. Integration personnel also work closely with electronics personnel when installing electronic packages and routing electrical harnesses.

3.5.5 FIELD SUPPORT

When required, Division personnel are available for field support at contractor sites, launch sites, and other NASA installations. Typical operations performed during field support tasks are covered above.

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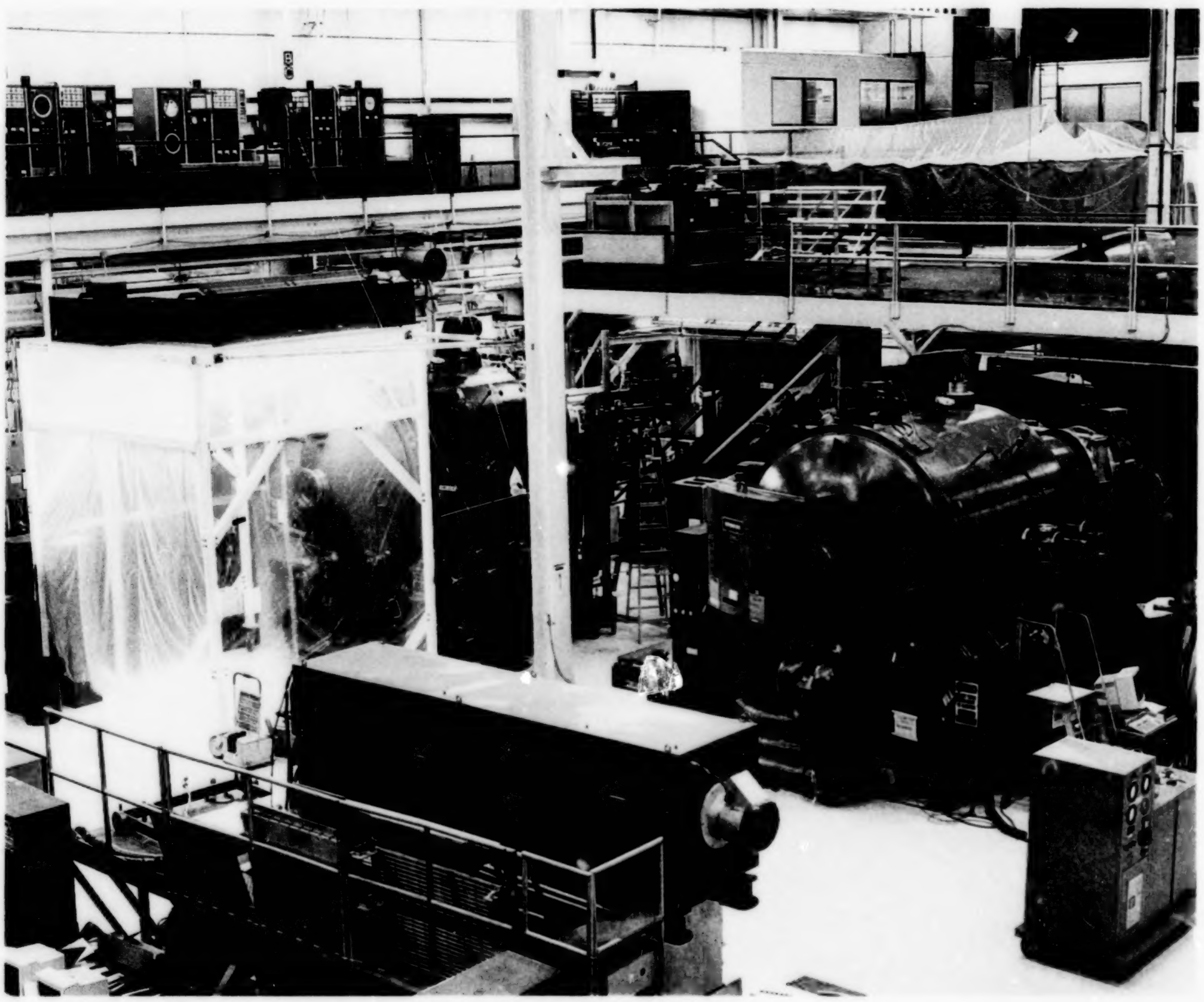
3.6 SPACE SIMULATION TEST ENGINEERING

INTRODUCTION

This section provides a summary of the environmental capabilities and dimensions of the test facilities of the Space Simulation Test Engineering Section. The test facilities are operated under continuous, 24-hour per day, monitoring by an operator.

It should be noted that the test volume measurements of each facility are the nominal dimensions of the thermal shroud, unless there is no shroud, and that the evacuation times are for a clean, dry and empty chamber. These data indicate the maximum capabilities of a facility. Lesser levels and decreased rates can be accomplished to accommodate payload requirements.



3.6.1 CAPABILITIES SUMMARY (SI UNITS)

FACILITY		NOMINAL SPECIFICATIONS (SI UNITS)			
Type	Number	Test Volume (meters)	Operating Pressure (pascal)	Temperature Range (°C)	Unique Capabilities
Temperature	204	0.51 x 0.41 x 0.31	Ambient	-150 to 300	
Temp/Humid	232	1.22 x 1.22 x 1.22	Ambient	-73 to 100	Humidity 15% to 95% RH
Thermal Vacuum	223	0.81 D x 2.44 H	<13.3 μpa	<2.0°K to ambient	Superfluid LHe shroud
	225	2.74 D x 4.27 L	<13.3 μpa	-190 to 100	C/F, TQCM, RGA
	237	2.13 D x 2.44 L	<67 μpa	-190 to 100	C/F, TQCM, RGA
	238	3.40 D x 4.32 H	<67 μpa	-190 to 90	Cryopump, C/F, TQCM, RGA
	239	2.13 D x 2.44 L	<67 μpa	-190 to 100	Cryopump, C/F, TQCM, RGA
	240	0.91 D x 0.91 L	<13.3 μpa	-160 to 110	C/F, TQCM, RGA
	241	0.91 D x 0.91 L	<13.3 μpa	-160 to 110	Cryopump, C/F, TQCM, RGA
	243/244	0.61 D x 0.61 H	<67 μpa	-190 to 100	C/F, TQCM, RGA
	281	0.91 D x 1.22 L	<213 μpa	-185 to 100	Cryopump, C/F, TQCM, RGA
	290	8.23 D x 12.19 H	<13.3 μpa	-180 to 75	8 Cryopumps
Rapid Pump Down	208	NA	1.33 pa	NA	Pump down 237 & 239 in 5 minutes
Thermal Systems Portable	201	NA	NA	-140 to 140	GN_2 Transfer medium
	205	NA	NA	-100 to 100	GN_2 Transfer medium
	206	NA	NA	-140 to 100	GN_2 Const dens trans med
	207	NA	NA	-140 to 100	GN_2 Transfer medium
	242	NA	NA	-100 to 100	Electrical heater controller
Solar Simulator Portable	211	NA	NA	NA	61cm dia, 1 SC
	213	NA	NA	NA	33cm dia, 1 SC
	218	NA	NA	Narrow beam lens	31cm, 0.5 to 16 SC, Filtered 31cm, 0.5 to 25 SC, Unfiltered
				Wide beam lens	102cm, 0.5 to 1 SC, Filtered 102cm, 0.5 to 1.5 SC, Unfiltered
Emergency Power	253	NA	NA	NA	250KVA, 480V, 3-Phase
	254	NA	NA	NA	500KVA, 480V, 3-Phase
High Press GN_2	257	NA	NA	NA	12.8 Mpa
	258	NA	NA	NA	12.8 Mpa

3.6.1 CAPABILITIES SUMMARY (ENGLISH UNITS)

FACILITY		NOMINAL SPECIFICATIONS (ENGLISH UNITS)			
Type	Number	Test Volume (feet)	Operating Pressure (torr)	Temperature Range (°F)	Unique Capabilities
Temperature	204	1.67 x 1.34 x 1.00	Ambient	-238 to 572	
Temp/Humid	232	4 x 4 x 4	Ambient	-100 to 212	Humidity 15% to 95% RH
Thermal Vacuum	223	2.65 D x 8 H	$<10^{-7}$	<-456 to ambient	Superfluid LHe shroud
	225	9 D x 14 L	$<10^{-7}$	-310 to 212	C/F, TQCM, RGA
	237	7 D x 8 L	$<5 \times 10^{-7}$	-310 to 212	C/F, TQCM, RGA
	238	11 D x 14 H	$<5 \times 10^{-7}$	-310 to 194	Cryopump, C/F, TQCM, RGA
	239	7 D x 8 L	$<5 \times 10^{-7}$	-310 to 212	Cryopump, C/F, TQCM, RGA
	240	3 D x 3 L	$<10^{-7}$	-256 to 230	C/F, TQCM, RGA
	241	3 D x 3 L	$<10^{-7}$	-256 to 230	Cryopump, C/F, TQCM, RGA
	243/244	2 D x 2 H	$<5 \times 10^{-7}$	-310 to 212	C/F, TQCM, RGA
	281	3 D x 4 L	$<1.6 \times 10^{-6}$	-300 to 212	Cryopump, C/F, TQCM, RGA
	290	27 D x 40 H	$<10^{-7}$	-292 to 167	8 Cryopumps
Rapid Pump Down	208	NA	10^{-2}	NA	Pump down 237 & 239 in 5 minutes
Thermal Systems Portable	201	NA	NA	-220 to 284	GN_2 Transfer medium
	205	NA	NA	-148 to 212	GN_2 Transfer medium
	206	NA	NA	-220 to 212	GN_2 Const dens trans med
	207	NA	NA	-220 to 212	GN_2 Transfer medium
	242	NA	NA	-148 to 212	Electrical heater controller
Solar Simulator Portable	211	NA	NA	NA	24" dia, 1 SC
	213	NA	NA	NA	13" dia, 1 SC
	218	NA	NA	Narrow beam lens	12", 0.5 to 16 SC, Filtered 12", 0.5 to 25 SC, Unfiltered
				Wide beam lens	40", 0.5 to 1 SC, Filtered 40", 0.5 to 1.5 SC, Unfiltered
Emergency Power	253	NA	NA	NA	250KVA, 480V, 3-Phase
	254	NA	NA	NA	500KVA, 480V, 3-Phase
High Press GN_2	257	NA	NA	NA	1850 psi
	258	NA	NA	NA	1850 psi

3.6.2 TEMPERATURE - HUMIDITY
3.6.2.1 0.057M^3 (2FT^3) TEMPERATURE CHAMBER (FACILITY 204)

DESCRIPTION: This facility is a small temperature controlled chamber used for thermal conditioning of small components. The portable chamber loads through a front opening door that has a viewing window. The instrumented payload is installed in the chamber with no special handling or mounting fixtures, and is connected to the ground support equipment via a port.

MODE OF OPERATION: The chamber is cooled with liquid nitrogen and heated with electrical resistance elements. Typical cycling times from hot to cold, and from cold to hot, are 45 minutes and 65 minutes, respectively.

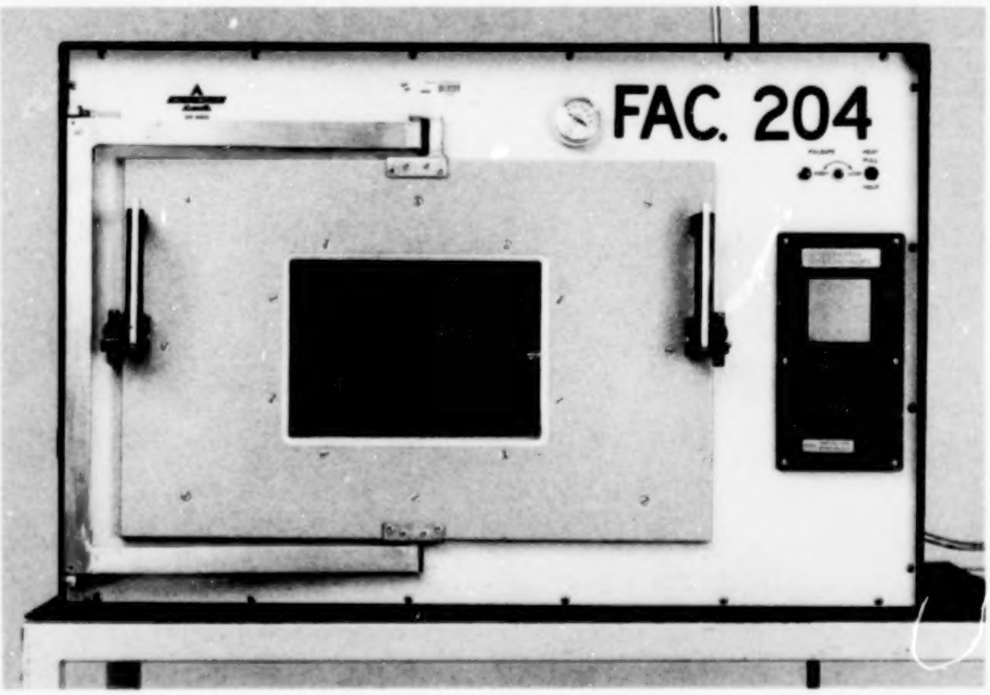
PARAMETERS:

Temperature range:	-150°C to 300°C (-238°F to 572°F)
Heating capacity:	3,300 watts
Cooling capacity:	100 watts at -150°C (-238°F)
Accuracy:	± 5°C (± 9°F)

PHYSICAL CHARACTERISTICS:

Chamber case:	84cm W x 71cm D x 61cm H (33" x 28" x 24")
Test volume:	51cm W x 41cm D x 31cm H (20" x 16" x 12")
Viewport size:	24cm x 17cm (9.5" x 6.5")
Power:	240 VAC, 3 phase, 13 amperes

INTEGRAL INSTRUMENTATION: Panel lights indicate power on, heating, and controlling modes. An internal thermocouple is connected to the chamber temperature controller. Twelve specimen thermocouples are connected to a data acquisition system.



3.6.2.2 1.81M³ (64FT³) TEMPERATURE - HUMIDITY CHAMBER (FACILITY 232)

DESCRIPTION: This facility is a medium-sized chamber used for thermal and humidity cycling of medium-sized test items. A full-opening, hinged front door with a window allows for access and viewing.

MODE OF OPERATION: The test item is installed in the chamber and connected to an external power source and data acquisition equipment via an access port. After ambient functional checks are completed, electrical heaters warm, and a cascade refrigeration system cools the air stream. A separate cooling unit provides dehumidification, and an electrically heated vapor generator provides humidification. The preferred procedure is to operate the chamber with a hot cycle before decreasing the temperature below 4°C (39°F). A dry nitrogen purge system regulates humidity in the chamber to prevent frost build-up on the test item.

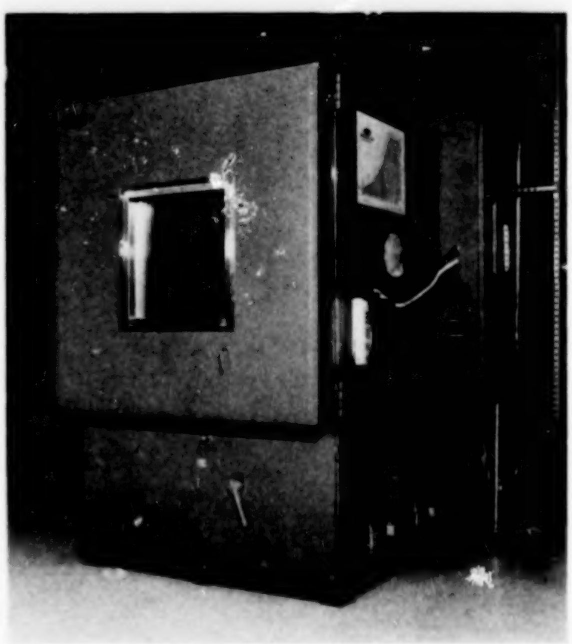
PARAMETERS:

Temperature range:	-73°C to 100°C (-100°F to 212°F)
Humidity range (RH):	15% to 95% (between 85°C (185°F) max and 4°C (39°F) min dewpoint)
Heating capacity:	18 Kw
Cooling capacity:	22 Kw

PHYSICAL CHARACTERISTICS:

Test volume:	122cm W x 122cm D x 122cm H (48" x 48" x 48")
Viewport size:	61cm x 61cm (24" x 24")
Access port size:	15.2cm inside diameter (6")

INTEGRAL INSTRUMENTATION: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber.



3.6.3 THERMAL VACUUM
3.6.3.1 LHe THERMAL VACUUM CHAMBER (FACILITY 223)

DESCRIPTION: The Instrument Test Dewar (ITD) provides the thermal vacuum environment for testing flight instruments at temperatures within a few degrees of absolute zero. The system consists of the ITD, vacuum systems for evacuating the ITD and lowering the LHe pressure and temperature, a cryogenic supply system, and a data acquisition system. The ITD consists of two concentric vacuum chambers, i.e., the Instrument Vacuum Space (IVS) and the Guard Vacuum Space (GVS) within an external shell. IVS and GVS are evacuated by separate cryopumps, which provide oil-free high vacuum pumping. The LHe cryogen is sub-cooled by lowering its vapor pressure with a blower and mechanical pump arrangement. Both vacuum systems are controlled from a central console.

MODE OF OPERATION: The IVS is cooled by the LHe shroud. Within the GVS is the liquid nitrogen shroud. The optical interface to the ITD is achieved by a 12-pin external optical fiber feedthrough connected to a blind mating assembly. Also, the ITD has provisions for the installation of optical windows. The system is capable of pumping on the LHe shroud for cool down from 4.2°K (-452°F) to superfluid helium temperatures. The Instrument Interface Flange (IIF) is bolted to the bottom of the LHe reservoir and provides the electrical, thermal, mechanical, and optical interface between the ITD and the payload. Instrumentation ports are at the top and bottom of the facility. A leak check is performed on all systems after installation of the payload.

PARAMETERS:

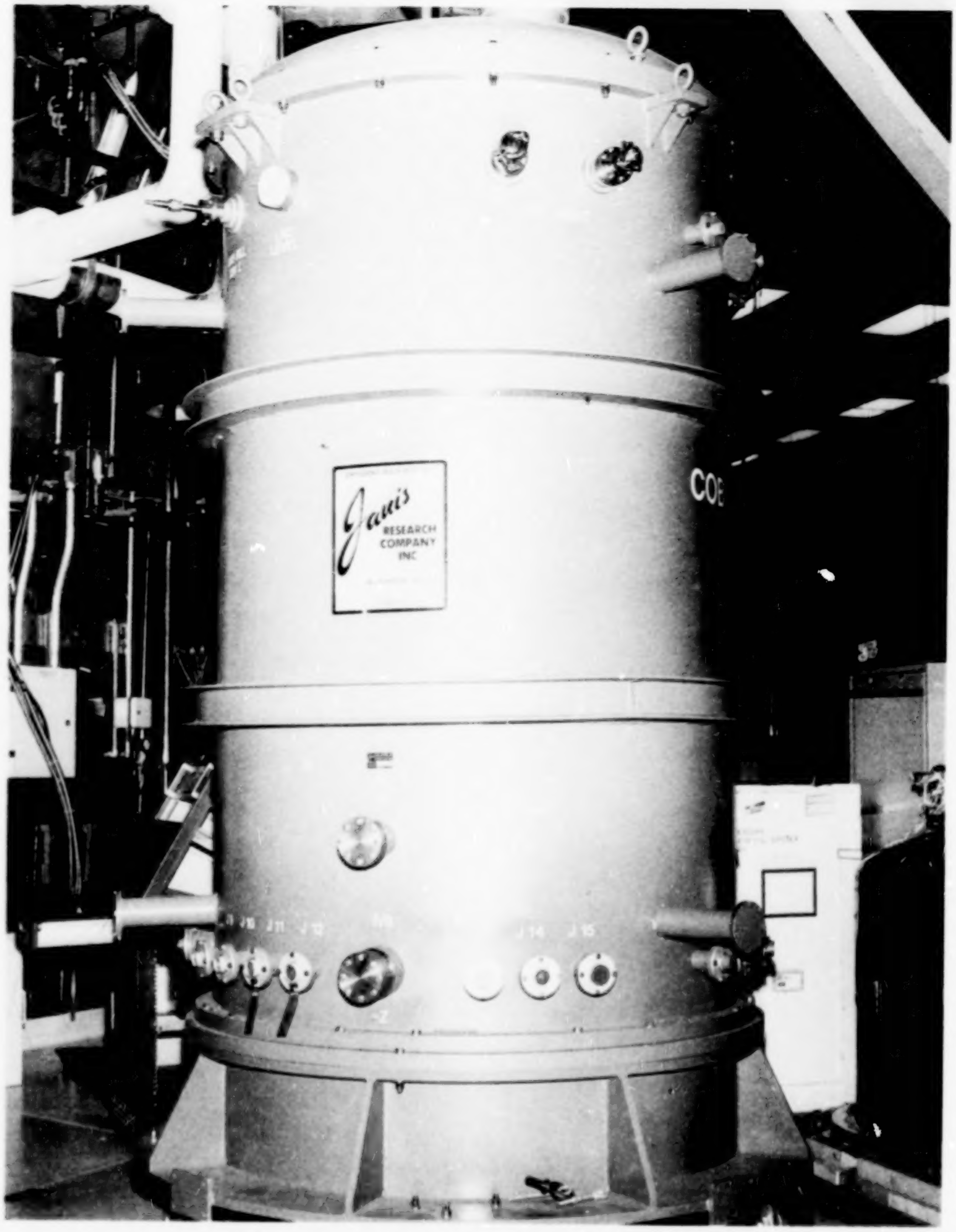
Pressure:	<13.3 μpa (1.0 x 10^{-7} torr)
Temperature range:	Minimum = <2°K (-456°F); maximum = ambient
Thermal sensors:	4 PRTs, 18 GRTs
Vibration sensors:	4 cryogenic accelerometers

PHYSICAL CHARACTERISTICS:

Chamber size:	1.52m dia x 3.35m H (5' x 11')
Test volume:	0.81m dia x 2.44m H (2.65' x 8')

DATA ACQUISITION: Two data acquisitions systems, one for the housekeeping sensors and one for payload sensors, are configured for the readout of up to 140 channels of 4-lead resistance measurements, 2-lead voltage measurements, or combinations of both. Temperature sensors such as germanium resistance thermometers (GRTs) and platinum resistance thermometers (PRTs) will be monitored in a 4-lead configuration. Strain gages can be either 4-lead or 2-lead devices.

FACILITY INTEGRATION: Electrical interface to the test item in the IVS is achieved via two sets of connectors. The protoflight connectors are located at the bottom section of the dewar and simulate the electrical interface to the flight dewar. Housekeeping connectors are at the top of the dewar and provide wiring for additional thermocouple, thermistor, accelerometer, and payload instrumentation. The ITD has provisions for the installation of optical windows for infrared experiments.



INSTRUMENT TEST DEWAR (FACILITY 223)

3.6.3.2 3.1M X 4.6M (10' X 15') THERMAL VACUUM CHAMBER (FACILITY 225)

DESCRIPTION: This chamber is a large, horizontal, cylindrical, thermal vacuum chamber used for thermal vacuum and thermal balance testing, and baking out large test items. Electrical feedthroughs and liquid and gas penetrations are provided at locations on the front, sides, and rear of the chamber.

MODE OF OPERATION: Test items are loaded by crane onto a load cart, which is rolled into the chamber on a rail system. Payload weight can be as high as 2,268 Kg (5,000 lb). The chamber door remains open while thermocouples are installed on the test item inside the chamber. A temperature controlled baseplate may be provided for high thermal dissipation.

Chamber evacuation is provided by 2 cryopumps, while roughing is provided by a blower and rotary vane mechanical pump. Shroud temperature conditioning is accomplished by a recirculating GN_2 thermal system, or it may be flooded with LN_2.

PARAMETERS:

Test pressure:	<13.3 μpa (1 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	40,000 lit (10,600 gal)/sec @ 133 μpa (10^{-6} torr)
Turbomolecular pumping speed:	1,000 lit (264 gal)/sec

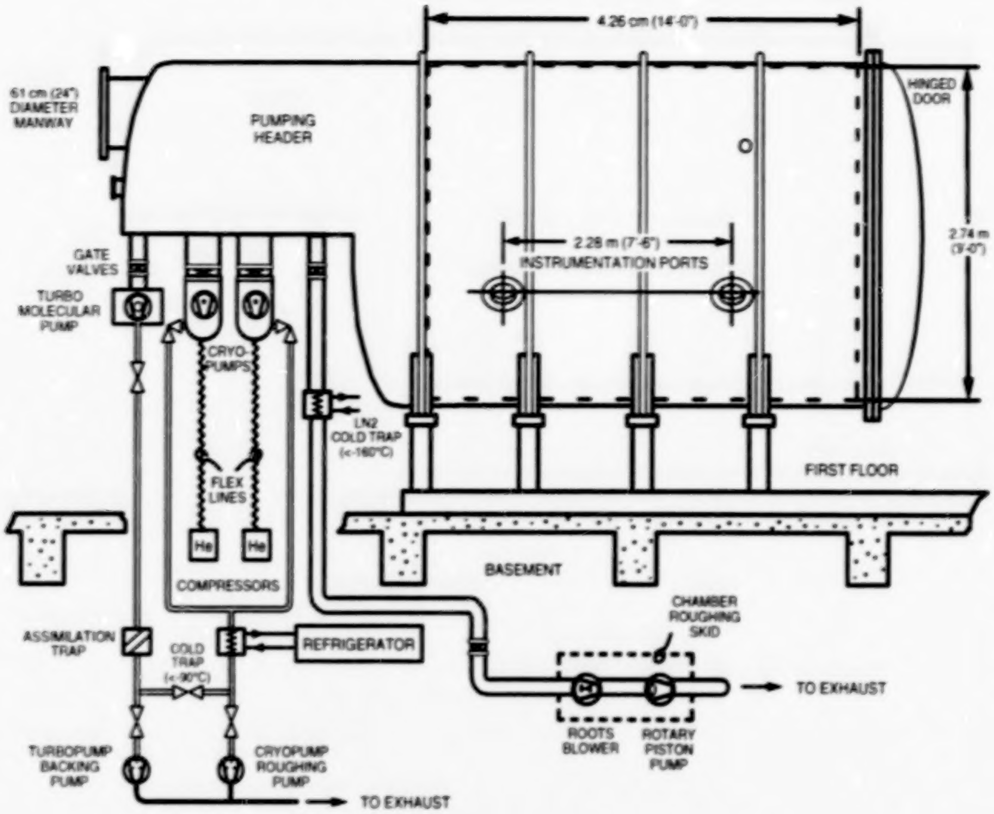
PHYSICAL CHARACTERISTICS:

Test volume:	2.74m dia x 4.27m L (9' x 14')
Payload support:	Wheeled cart - 2,268 Kg capacity (5,000 lb)
Instrumentation ports:	6 each 25.4cm dia (10"), 6 each 12.7cm dia (5")

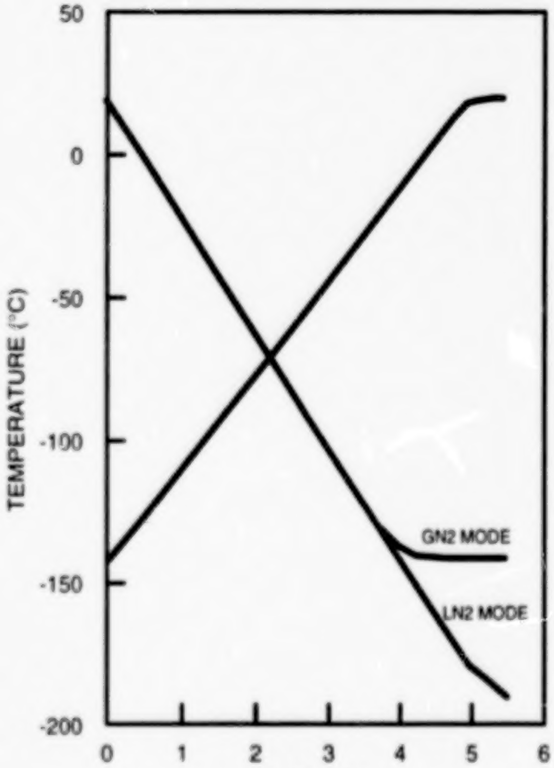
INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	200 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

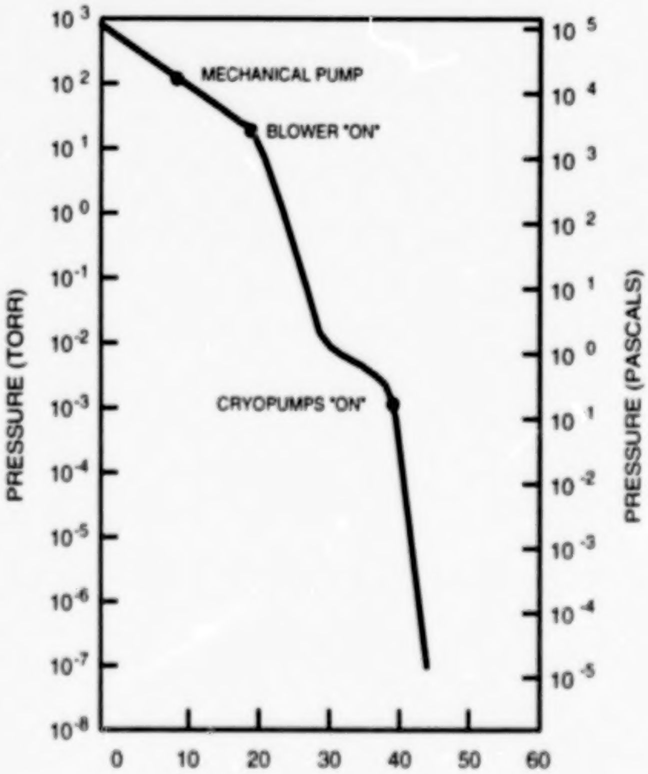
AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM) and contamination control mirrors.



CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 225



SHROUD TEMPERATURE PERFORMANCE



FAC. 225 PUMPDOWN

A918.003

3.6.3.3 2.1M X 2.4M (7' X 8') DIFFUSION PUMPED VACUUM CHAMBER (FACILITY 237)

DESCRIPTION: This is a horizontal, medium-sized, environmental test chamber equipped with a viewport to accommodate an external solar simulator. The facility is used for thermal vacuum and thermal balance testing, and baking out test items. Any of three solar simulators may be used for tests with solar requirements.

MODE OF OPERATION: The test item is mounted on the portable payload fixture which is positioned at the chamber door. An overhead rail is also available for mounting purposes. The payload is instrumented with thermocouples and rolled into the internal chamber. Ground support equipment cabling is connected through the penetration plates and ambient functional checks are performed. Prior to solar testing, it is normal to perform an alignment check of the test item with the external simulator.

Chamber evacuation is provided by a rotary piston mechanical pump and an oil diffusion pump. Rapid pump down can also be performed. A sliding gate main valve allows chamber access while the pumping systems are established. An auxiliary liquid helium cooled shroud can be installed to provide an ultracold payload environment.

PARAMETERS:

Test pressure:	<67 μpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Gimbal and spin can:	
Angle:	± 30° from vertical
Rotational speed:	0 to 100 RPM
Chamber pumping speed:	40,000 lit (10,600 gal)/sec
Evacuation time:	Atm to 133 μpa (10^{-6} torr) in 300 minutes
Diffusion pump established before opening main valve	

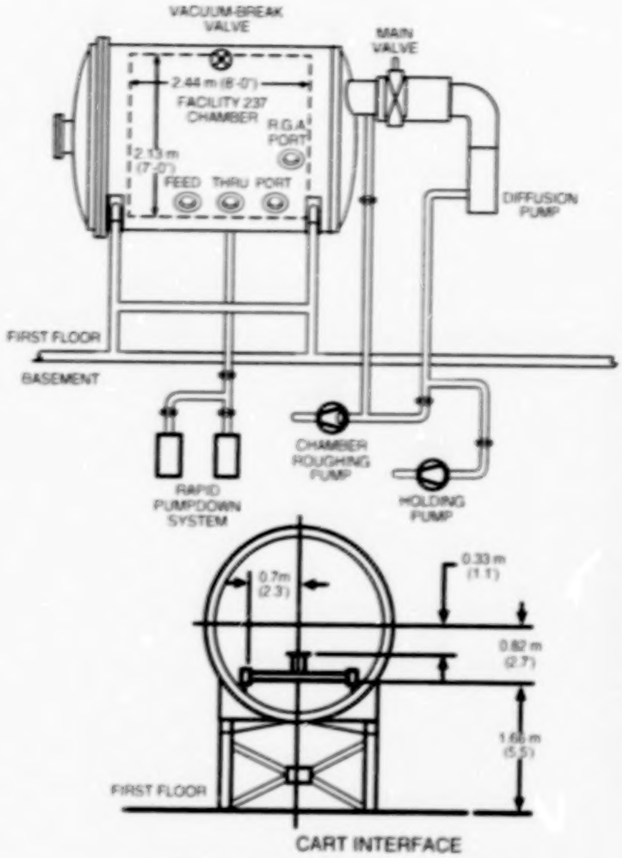
PHYSICAL CHARACTERISTICS:

Test volume:	2.13m dia x 2.44m L (7' x 8')
Viewport dimensions:	31cm dia (12") quartz window
Standard electrical feedthrough:	36 - 37 pin connectors (RF feedthroughs available on request)

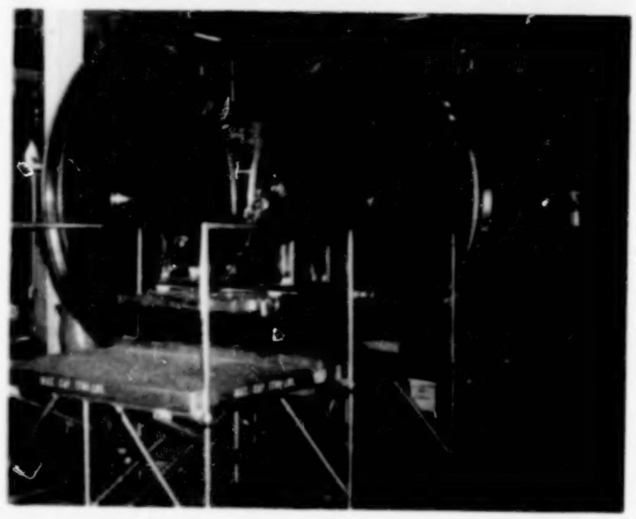
INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	54 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

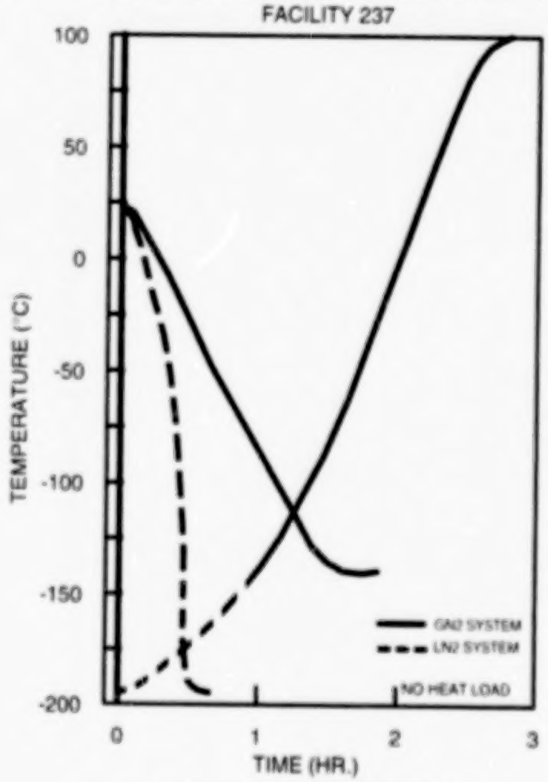
AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors. A portable clean tent can be installed over the payload and facility entrance during test setup. All portable solar systems can be used.



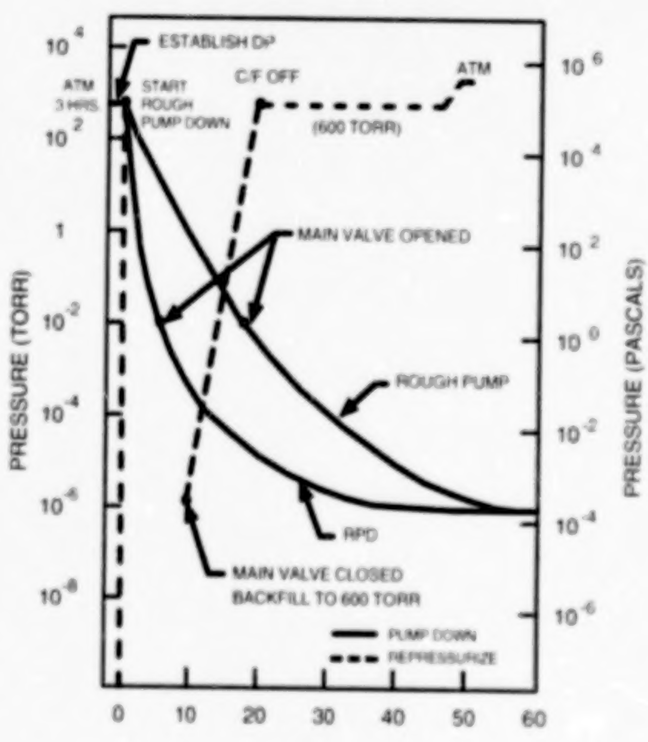
CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 237



CHAMBER VIEW



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.004

3.6.3.4 3.7M X 4.6M (12' X 15') CRYOPUMPED VACUUM CHAMBER (FACILITY 238)

DESCRIPTION: This vertical facility is a large, cylindrical thermal vacuum chamber which is used for thermal vacuum and thermal balance testing, and baking out spacecraft hardware. Test articles are normally loaded through the top of the chamber using the building crane; however, small payloads can be transported through the personnel entrance. Ports for electrical feedthroughs, liquid/gas feedthroughs, and viewing are located around the perimeter of the chamber. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

MODE OF OPERATION: With the chamber dome rolled back, the overhead crane is used to lower the payload onto the support fixture. In most cases, special fixturing must be designed due to the uniqueness of the test article support system. Once installed, the payload is instrumented and connected to the ground support equipment via feedthroughs. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Initial chamber evacuation is provided by two rotary piston mechanical pumps, with four closed cycle cryopumps for high vacuum pumping. Each cryopump is isolated from the chamber by a sliding gate main valve to allow off-line cool down and regeneration.

PARAMETERS:

Test pressure:	<67 μpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-90°C to 90°C (-130°F to 194°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	1.8 x 10^4 lit (4,800 gal)/sec N_2 @ 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 133 μpa (10^{-6} torr) in 2 hours

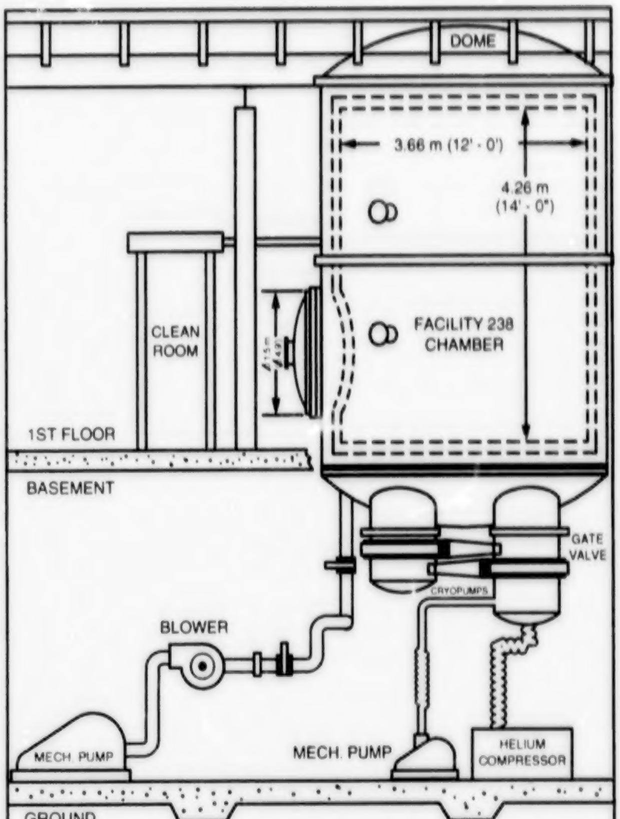
PHYSICAL CHARACTERISTICS:

Test volume:	3.4m D x 4.3m H (11'2" x 14'2")
Payload support:	Floor level - 1.2m (4') square platform
	Side wall - hard points at 1.8m and 3.7m (6' and 12') levels
Personnel door:	1.5m (5') diameter
Crane capacity:	4,536 Kg (5 ton)
Viewport dimensions:	23cm (9") diameter
Standard elec. feedthroughs:	36 - 37 pin connectors (RF feedthroughs available on request)

INTEGRAL INSTRUMENTATION:

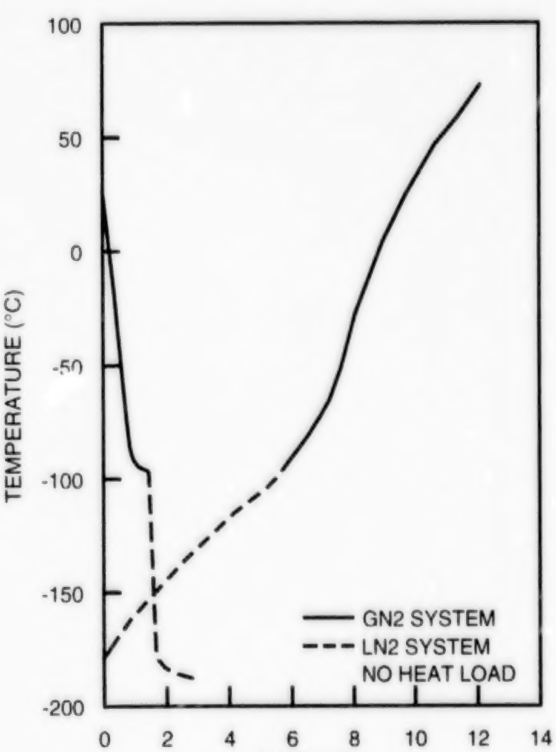
Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	300 thermocouple or thermistor channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.

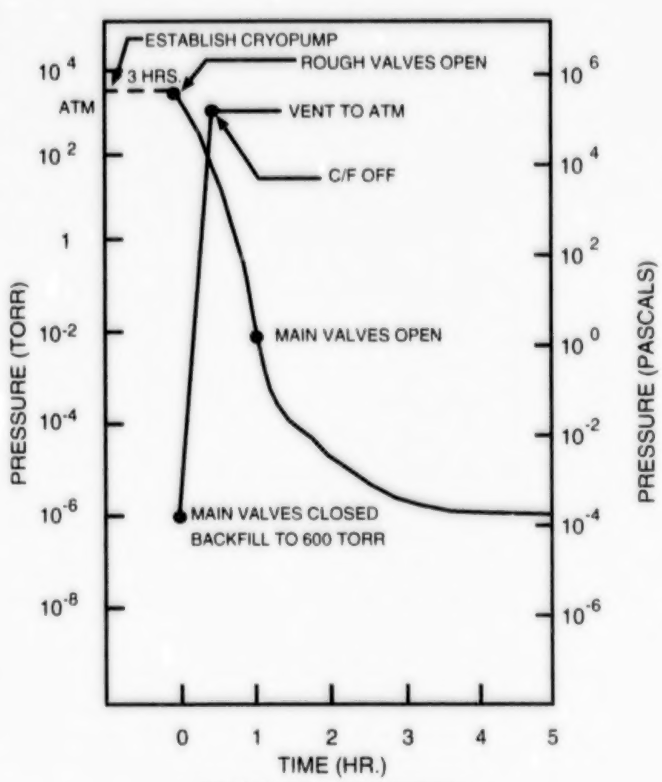


CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 238

CHAMBER VIEW



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.005

3.6.3.5 2.1M X 2.4M (7' X 8') CRYOPUMPED VACUUM CHAMBER (FACILITY 239)

DESCRIPTION: This horizontal, medium-sized, thermal vacuum test chamber is equipped with a viewport to accommodate an external solar simulator. Chamber evacuation is provided by a rotary piston mechanical pump and cryopumping system. A sliding gate main valve allows chamber access while the cryopumping system is being established. The facility is used for thermal vacuum and thermal balance testing, and baking out test articles. Any of three solar simulators may be used for tests with solar requirements. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

MODE OF OPERATION: The test article is mounted on the portable payload fixture which is pre-positioned at the chamber door. An overhead rail is also available for mounting purposes. After instrumenting the payload with thermocouples, it is rolled into the chamber. Ground support equipment cabling is connected through the penetration plates, and ambient functional checks are performed. An auxiliary liquid helium-cooled shroud can provide an ultracold payload environment. The cryopump requires 4 hours establishing time prior to chamber pump down.

PARAMETERS:

Test pressure:	<67 μpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-160°C to 100°C (-256°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Gimbal and spin can:	
Angle:	± 30° from vertical
Rotational speed:	0 to 100 RPM
Chamber pumping speed:	1,000 lit (264 gal)/sec
Evacuation time:	Atm to 1.3 pa (10^{-2} torr) in 1 hour
	1.3 pa to 133 μpa (10^{-6} torr) in 5 hours

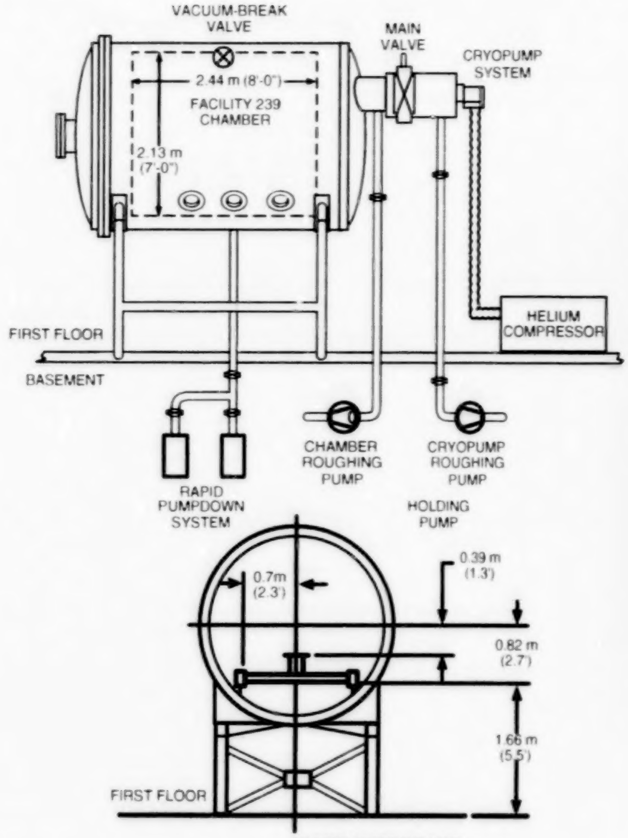
PHYSICAL CHARACTERISTICS:

Test volume:	2.1m diameter x 2.4m L (7' x 8')
Viewport dimensions:	30cm (12") diameter quartz window
Standard elec. feedthroughs:	36 - 37 pin connectors (RF feedthroughs available on request)

INTEGRAL INSTRUMENTATION:

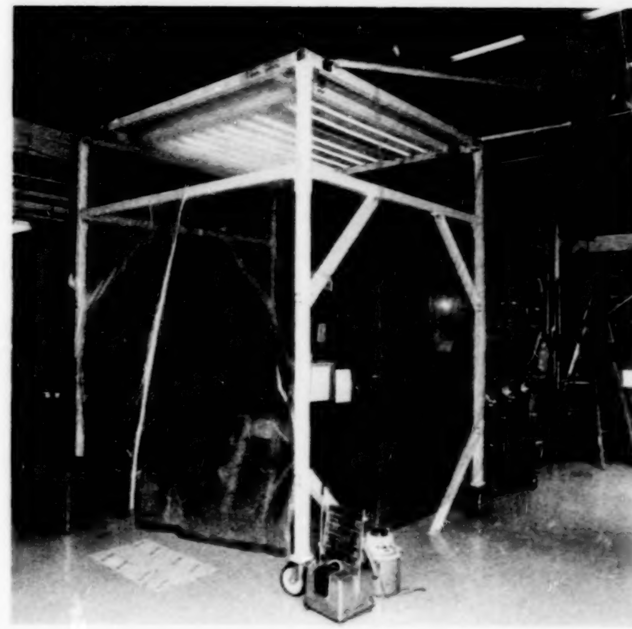
Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	54 thermocouple channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors. All portable solar systems can be used.

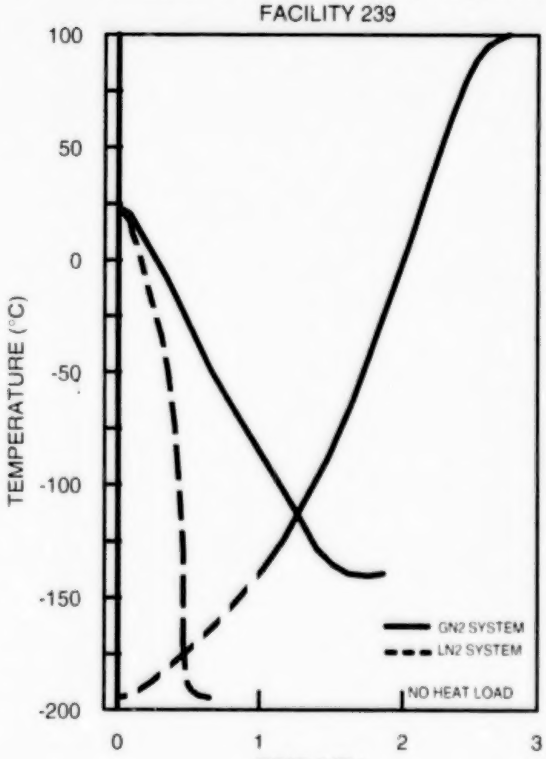


CART INTERFACE

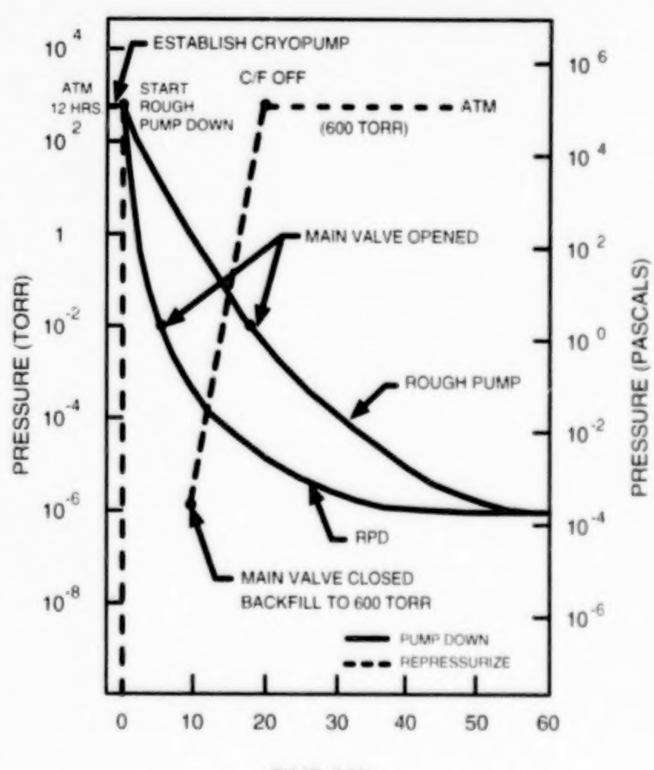
CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 239



CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.006

3.6.3.6 0.9M X 0.9M (3' X 3') DIFFUSION PUMPED VACUUM CHAMBER (FACILITY 240)

DESCRIPTION: This diffusion pumped facility is a horizontal, cylindrical, small-sized, thermal vacuum test chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall.

MODE OF OPERATION: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plates, and ambient functional checks are performed. Placing the test article on a baseplate or suspending it from the overhead rail are acceptable mounting methods. Chamber evacuation is provided by rotary piston mechanical pumps and an oil diffusion pump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<13.3 μpa (10^{-7} torr)
Shroud temperature:	-160°C to 110°C (-256°F to 230°F)
Chamber pumping speed:	1,200 lit (317 gal)/sec at 13 mpa (10^{-4} torr)
Evacuation time:	Atm to 133 μpa (10^{-6} torr) in 2 hours

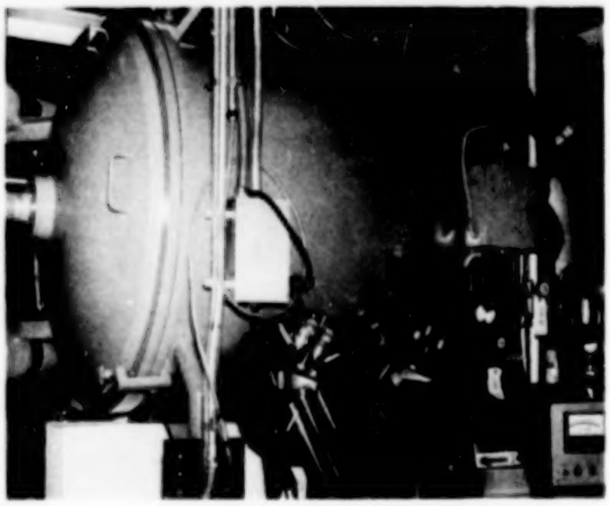
PHYSICAL CHARACTERISTICS:

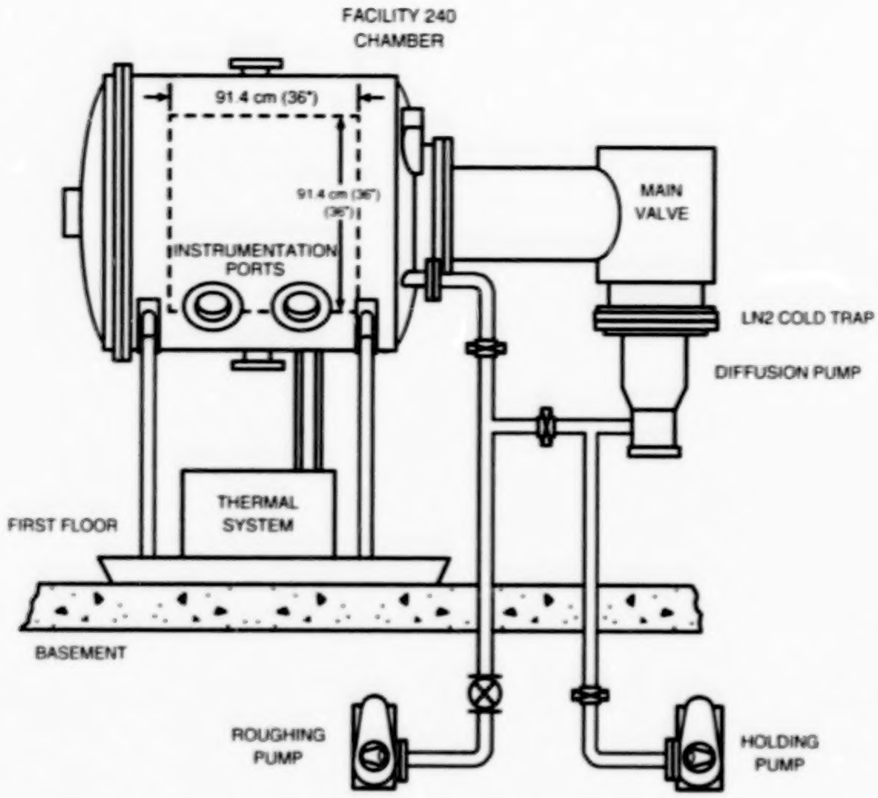
Test volume:	0.91m diameter x 0.91m L (3' x 3')
Standard elec. feedthroughs:	24 - 37 pin connectors (RF feedthroughs available on request)

INTEGRAL INSTRUMENTATION:

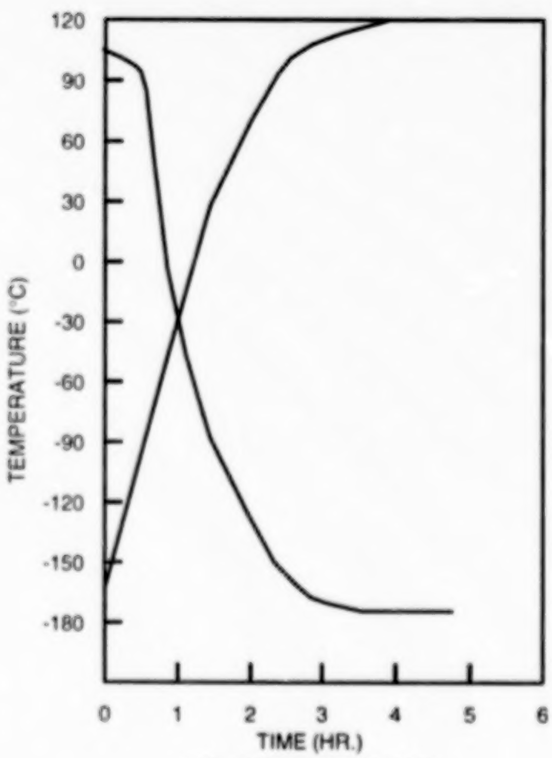
Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	12 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors.

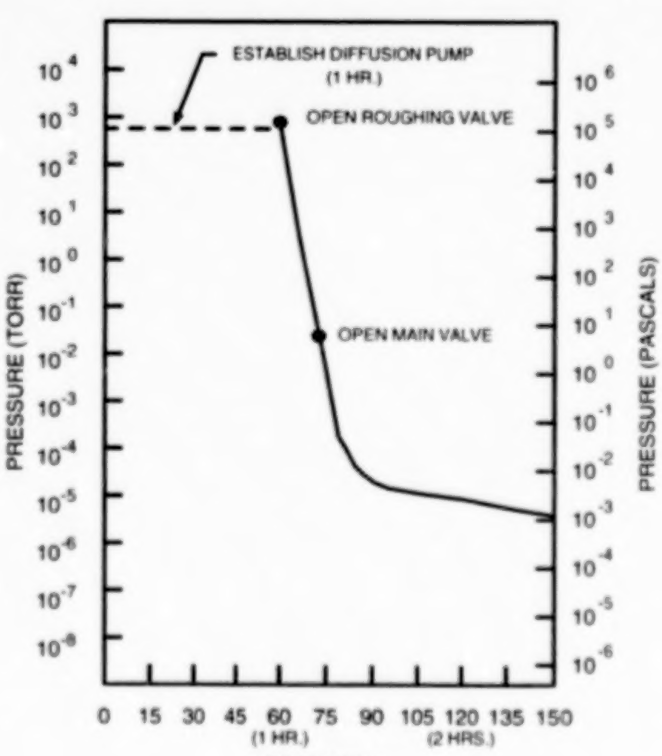




CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 240



SHROUD TEMPERATURE
PERFORMANCE



PRESSURE PARAMETERS

A918.007

3.6.3.7 0.9M X 0.9M (3' X 3') CRYOPUMPED VACUUM CHAMBER (FACILITY 241)

DESCRIPTION: This cryopumped facility is a horizontal, cylindrical, small-sized, thermal vacuum chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall.

MODE OF OPERATION: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. After roughing down the chamber with the rotary piston mechanical pump, ultimate pressure is achieved with the cryopump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<13.3 μpa (10^{-7} torr)
Shroud temperature:	-160°C to 110°C (-256°F to 230°F)
Chamber pumping speed:	865 lit (229 gal)/sec at 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 13.3 pa (10^{-1} torr) in 5.5 minutes
	13.3 pa to 13.3 μpa (10^{-7} torr) in 2 hours

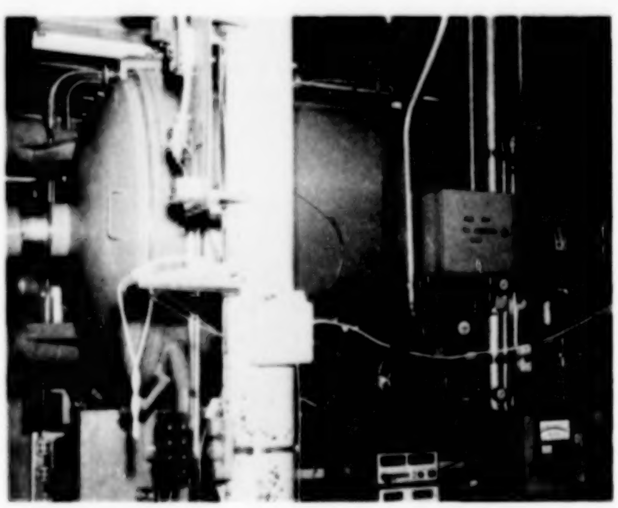
PHYSICAL CHARACTERISTICS:

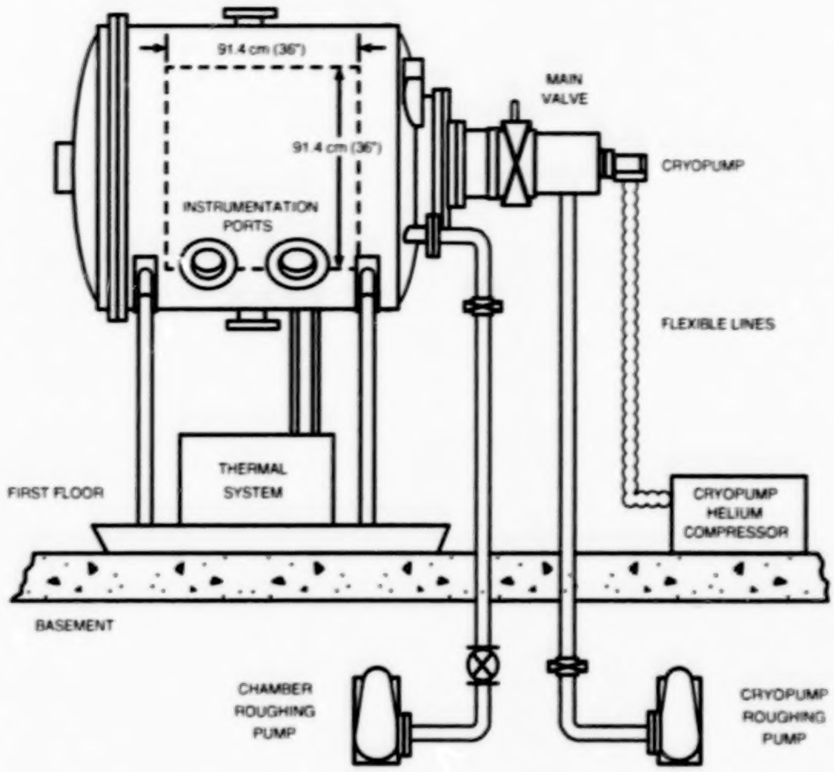
Test volume:	0.91m diameter x 0.91m L (3' x 3')
Standard elec. feedthroughs:	24 - 37 pin connectors (RF feedthroughs available on request)

INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	12 thermocouple channels
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

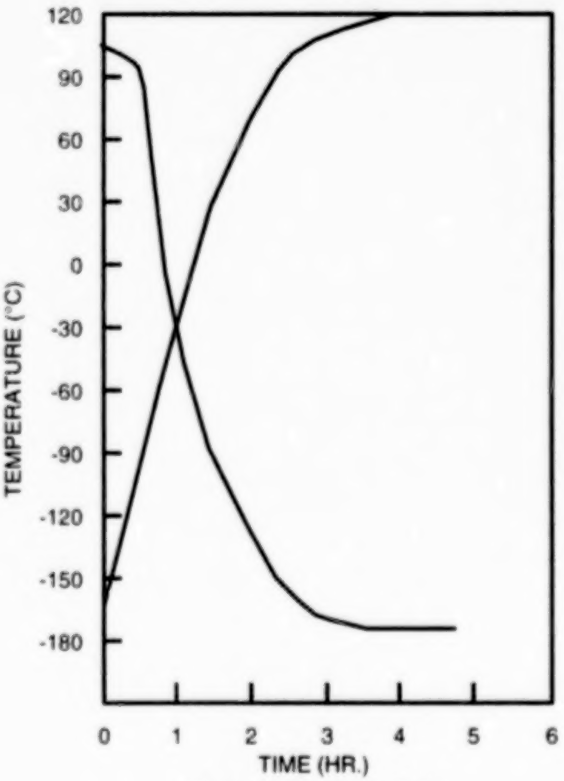
AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



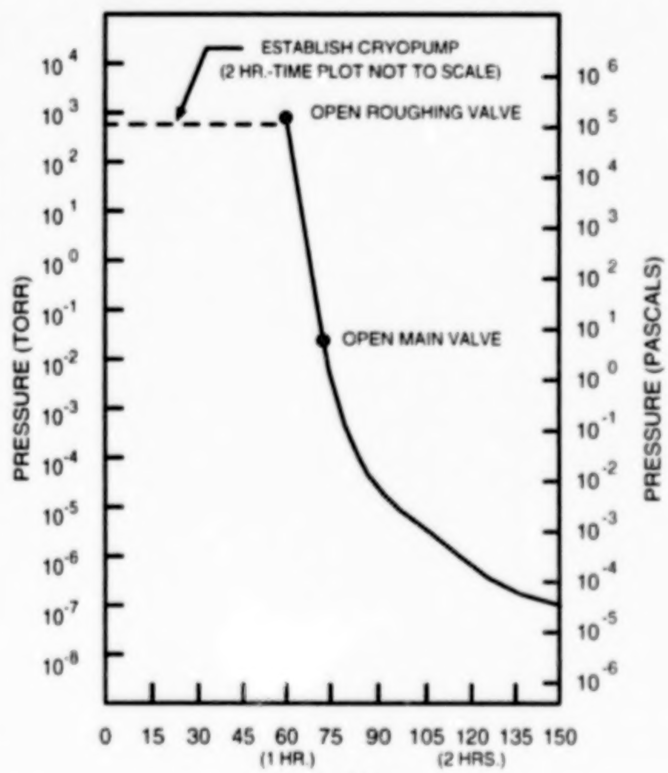


CHAMBER & VACUUM SYSTEM SCHEMATIC

FACILITY 241



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.008

3.6.3.8 0.6M X 0.6M (2' X 2') VACUUM CHAMBERS (FACILITIES 243 AND 244)

DESCRIPTION: These diffusion pumped facilities are vertical, top-loading, cylindrical "belljar" test chambers used for thermal vacuum and thermal balance testing, and baking out test hardware. They are equipped with a viewport to accommodate an external solar simulator.

MODE OF OPERATION: The test article is mounted to a fixture suspended from the chamber lid. After the payload is instrumented with thermocouples, the lid is placed on the chamber. Ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. For solar testing, it is normal to perform an alignment check with the external simulator prior to pump down. During temperature cycling, soak periods are observed for functional checks as specified in the test plan.

Chamber evacuation is provided by rotary piston mechanical pumps and an oil diffusion pump. A sliding gate main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	<67 µpa (5 x 10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-140°C to 100°C (-220°F to 212°F)
LN_2 mode:	-190°C (-310°F)
Chamber pumping speed:	300 lit (79 gal)/sec at 1.3 mpa (10^{-5} torr)

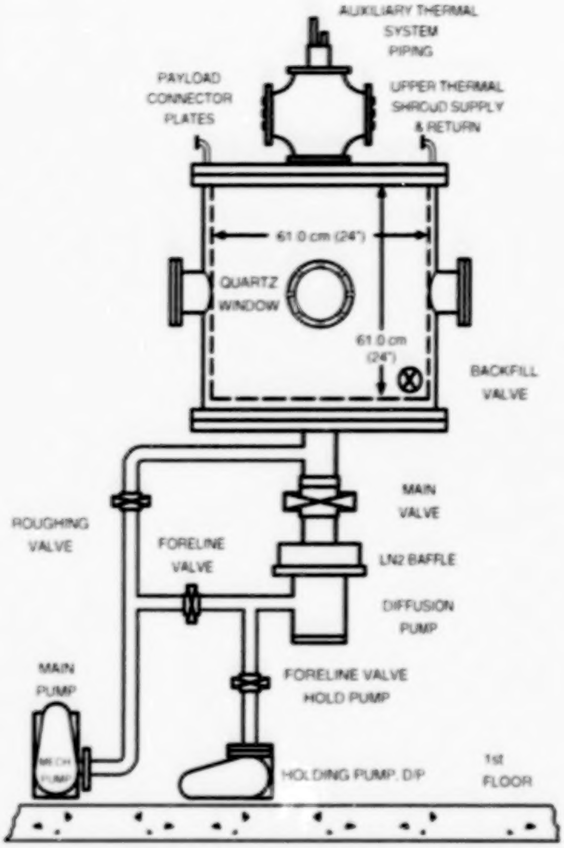
PHYSICAL CHARACTERISTICS:

Test volume:	0.61m dia x 0.61m H (2' x 2')
Hoist capacity:	454 Kg (1,000 lb)
Viewport dimensions:	19cm dia (7.5") quartz window
Standard electrical feedthrough:	8 - 37 pin connectors (RF feedthroughs available on request)

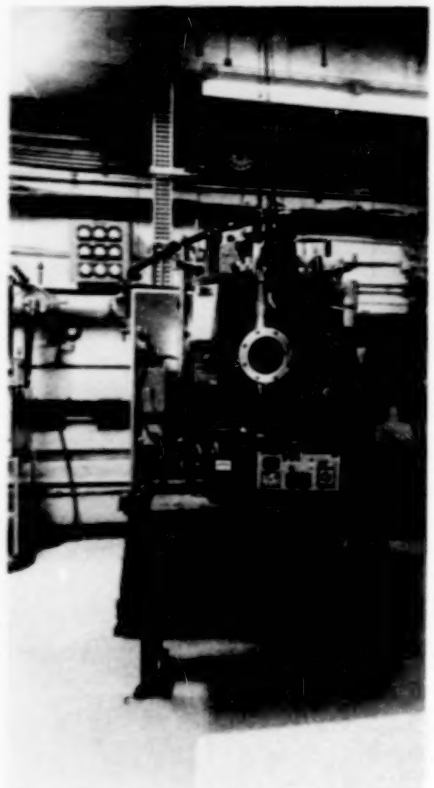
INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer - atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	12 thermocouple channels
Contamination:	TQCM, cold finger, residual gas analyzer

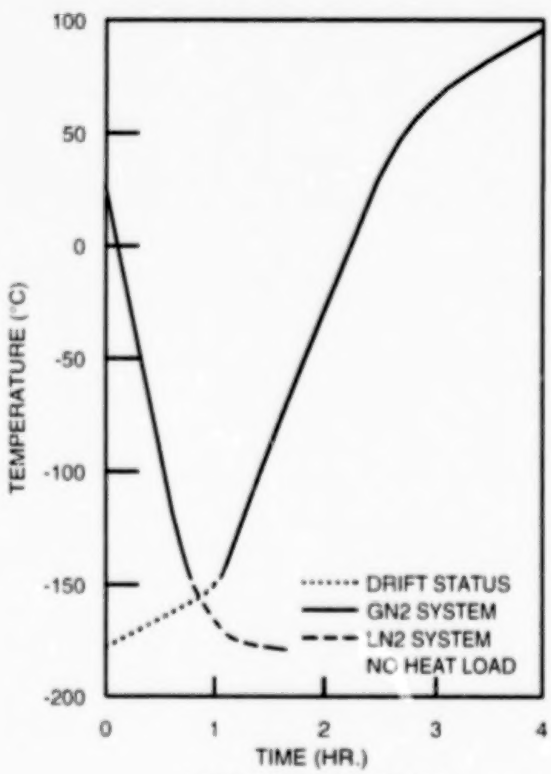
AUXILIARY EQUIPMENT: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors. Also, a portable solar simulator can be used to illuminate the payloads.



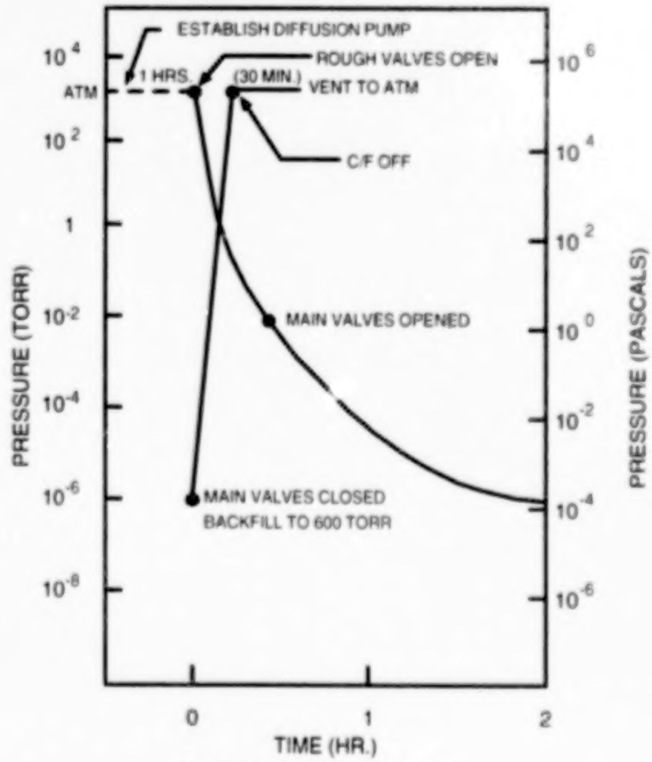
CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 243 & 244



CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE



PRESSURE PARAMETERS

A918.009

3.6.3.9 0.9M X 1.2M (3' X 4') CRYOPUMPED VACUUM CHAMBER (FACILITY 281)

DESCRIPTION: This cryopumped facility is a horizontal, cylindrical, medium-sized, thermal vacuum chamber used for thermal vacuum testing and baking out test articles. The payload is mounted on a plate which is attached to rails in the chamber.

MODE OF OPERATION: After the test article is instrumented and installed in the chamber, it is connected to the ground support equipment and data acquisition system via electrical feedthroughs. After roughing down the chamber with the mechanical pump, ultimate pressure is achieved with a cryopump. A main valve allows test set up while the pumping system is being established.

PARAMETERS:

Test pressure:	213 μpa (1.6 x 10^{-6} torr)
Shroud temperature:	
GN_2 mode:	-150°C to 100°C (-238°F to 212°F)
LN_2 mode:	-185°C (-300°F)
Chamber pumping speed:	865 lit (229 gal)/sec N_2 at 133 μpa (10^{-6} torr)
Evacuation time:	Atm to 13.3 pa (10^{-1} torr) in 5.5 minutes
	13.3 pa to 213 μpa (1.6 x 10^{-6} torr) in 2 hours

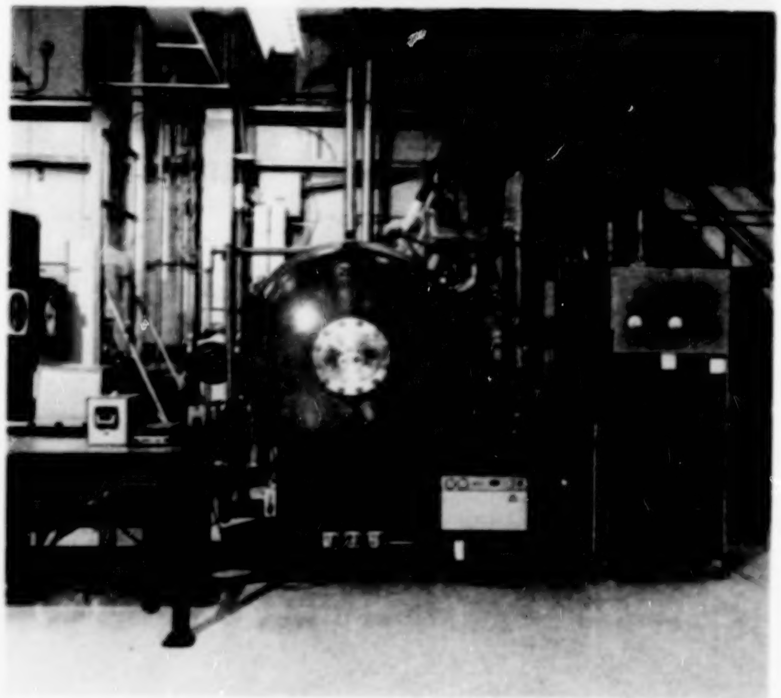
PHYSICAL CHARACTERISTICS:

Test volume:	0.91m diameter x 1.22m L (3' x 4')
Payload support:	Plate on support rails
Standard elec. feedthroughs:	4 - 37 pin connectors

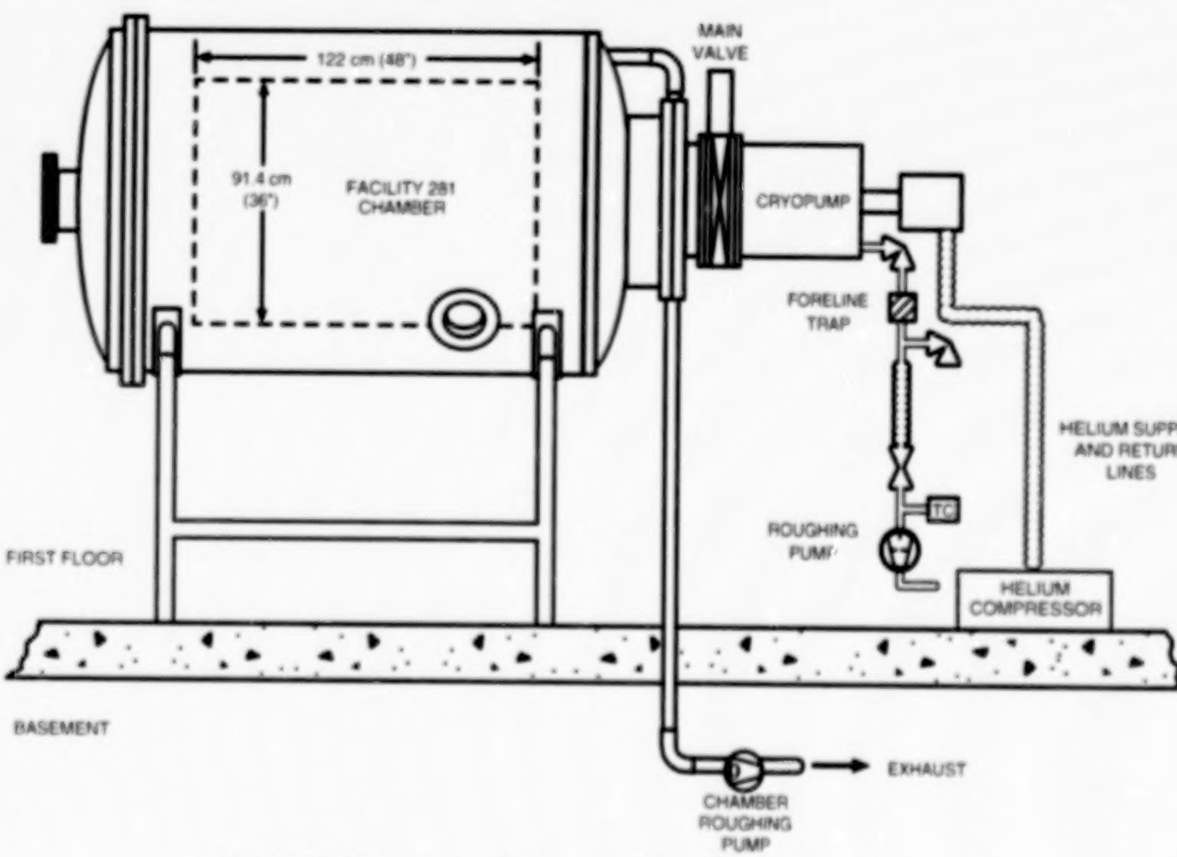
INTEGRAL INSTRUMENTATION:

Pressure:	T/C gauge - atm to 0.13 pa (10^{-3} torr)
	Capacitance manometer - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge - 0.13 pa (10^{-3} torr) to ultimate
Contamination monitor:	TQCM, coldfinger, residual gas analyzer

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



CHAMBER VIEW



CHAMBER & VACUUM SYSTEM SCHEMATIC
FACILITY 281

A918.010

3.6.3.10 8.2M X 12.2M (27' X 40') CRYOPUMPED VACUUM CHAMBER (FACILITY 290)

DESCRIPTION: This cryopumped facility is a vertical, very large Space Environment Simulation (SES) test chamber capable of achieving ultra low pressure and a wide range of thermal conditions. Test articles are loaded through the top of the chamber using the Building 10 crane. Personnel entry is through a side opening access port. Two small viewports are located on the chamber side at different elevations. The chamber is used for thermal vacuum and thermal balance testing, and baking out very large test articles.

MODE OF OPERATION: The test article is loaded onto the payload table or internal fixturing with the chamber dome rolled back. Often, special fixturing is required. An external clean air supply provides fresh air to the chamber during pre-test activities. Entry to instrument the payload with thermocouples, connect ground support equipment cabling, and install hardware is through a cleanroom airshower at the personnel door. Wearing of clean garments is required. Scaffolding may be erected to provide access to the payload. An area adjacent to the main facility control console is reserved for the experimenter's ground support equipment. Ambient functional checks are normally performed. During temperature cycling, soak periods are observed for functional checks as specified in the test plan. A computer data terminal is provided with packaged software routines for temperature monitoring.

Chamber evacuation is provided by eight rotary piston mechanical pumps with Roots blowers, and eight cryopumps. A turbomolecular pump is available to pump the lighter gasses to achieve ultra low pressures. Thermal control is provided by an aluminum tube-in-sheet cylindrical shroud with both liquid nitrogen and gaseous nitrogen operational modes. The dome and bottom shrouds are also connected to the thermal skids. Resistance heater arrays, with external power supplies or gaseous nitrogen panels, are available for special thermal requirements. A thermoelectric quartz crystal microbalance (TQCM) and residual gas analyzer (RGA) provide both quantitative and qualitative monitoring of molecular contamination and gaseous constituents within the chamber. Closed circuit television coverage is available for monitoring the test article.

EXPERIMENTER'S INTERFACE PANEL (EIP): A transportable, programmable logic controller (PLC)-based EIP is available for the facility, and can be positioned as required. The EIP has access to chamber pressure, cryopump pressure, temperature data, and any fault or operator warnings, with one-tenth-second response time. This system can provide audio warnings and power interrupt to the experimenter as a function of chamber pressure. Also, all information that is available on the chamber operator's color graphics display is available at the EIP. This includes valve positions, operational status of pumps, cold trap temperatures, cryopump baffle temperatures, and other similar operating parameters.

PARAMETERS:

Test pressure:	13.3 μpa (10^{-7} torr)
Shroud temperature:	
GN_2 mode:	-90°C to 75°C (-130°F to 167°F)
LN_2 mode:	-180°C (-292°F)
Chamber pumping speed:	
8 cryopumps:	2 x 10^5 lit (53,000 gal)/sec at 1.3 mpa (10^{-5} torr)
Turbomolecular pump:	6 x 10^3 lit (1,600 gal)/sec, helium and hydrogen

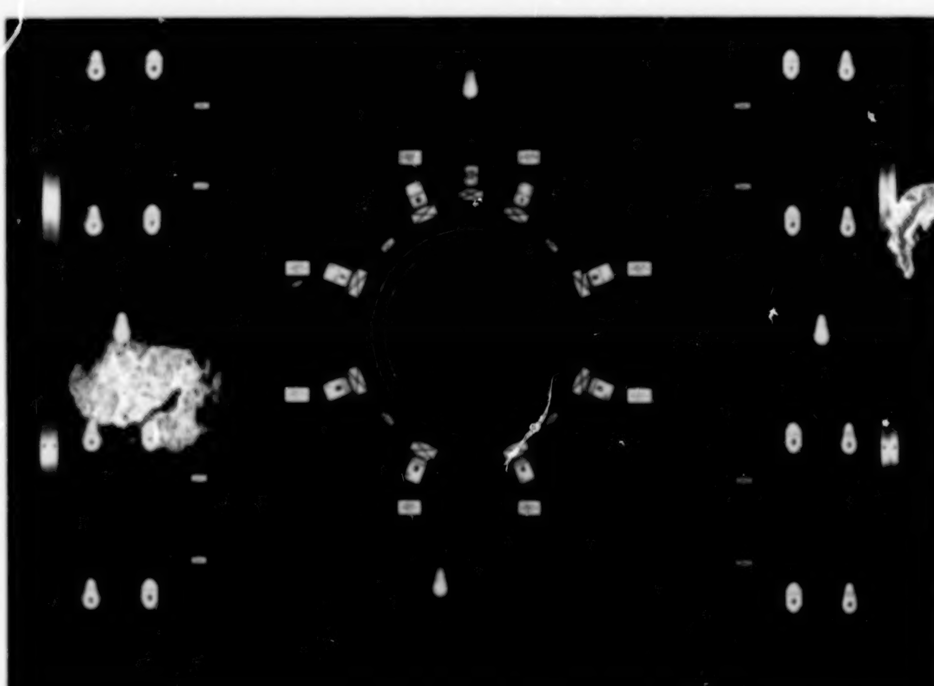
PHYSICAL CHARACTERISTICS:

Test volume:	8.23m diameter x 12.19m H (27' x 40')
Payload support:	9,072 Kg (20,000 lb)
Removable floor:	11,794 Kg (26,000 lb)
Viewports:	30 cm (12") two each
Standard elec. feedthroughs:	62 - 37 pin connectors
	6 - 7 pin connectors
	16 - 4 pin connectors (RF feedthroughs available on request)

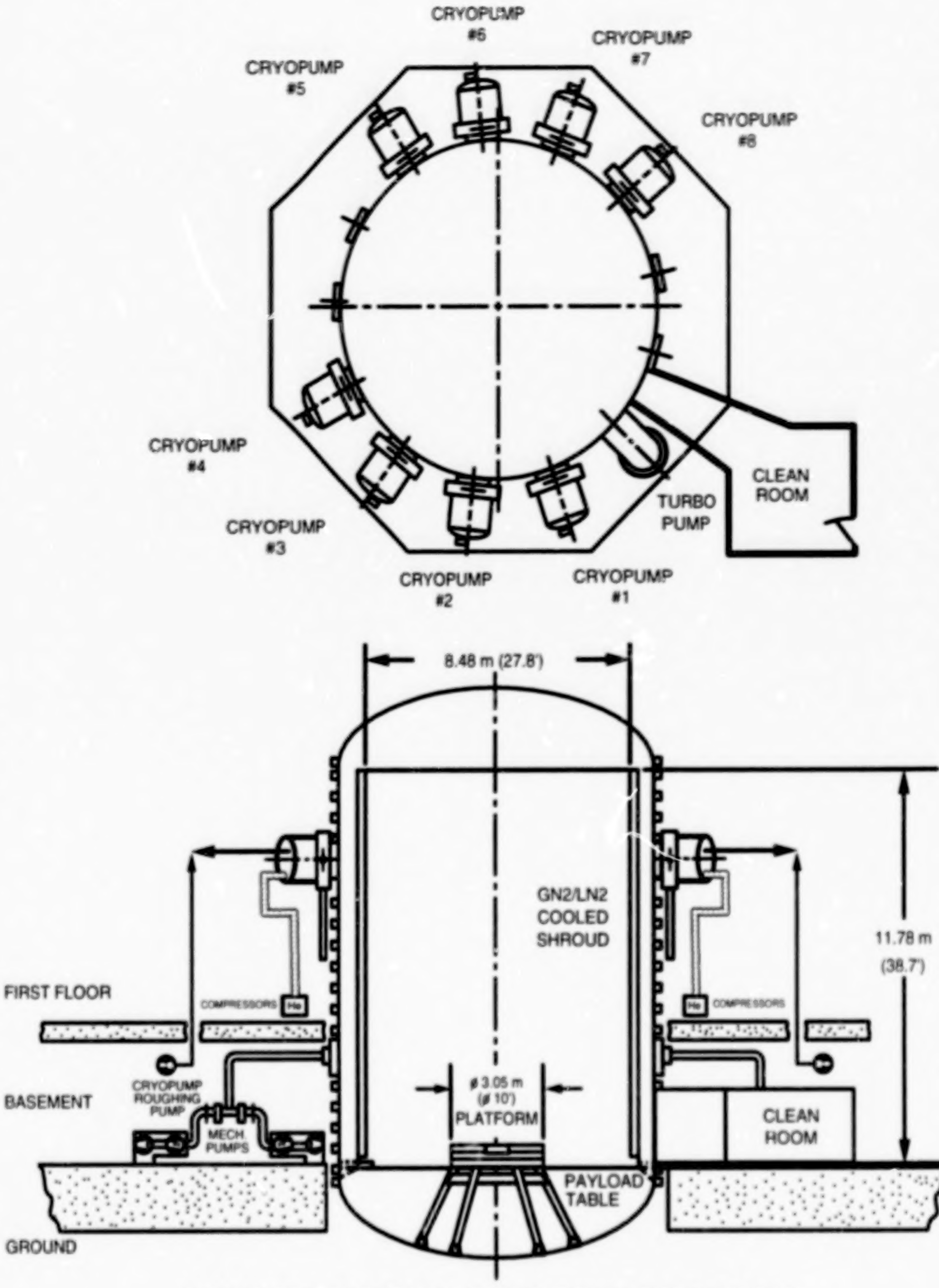
INTEGRAL INSTRUMENTATION:

Pressure:	Capacitance manometer (2) - Atm to 0.13 pa (10^{-3} torr)
	Ion gauge (4) - 0.13 pa (10^{-3} torr) to ultimate
Payload temperature:	600 channels of thermocouples, thermistors, or voltage signals
Contamination monitor:	TQCM, coldfinger, residual gas analyzer
TQCM frequencies:	4 - 15 MHz; 2 - 10 MHz

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.

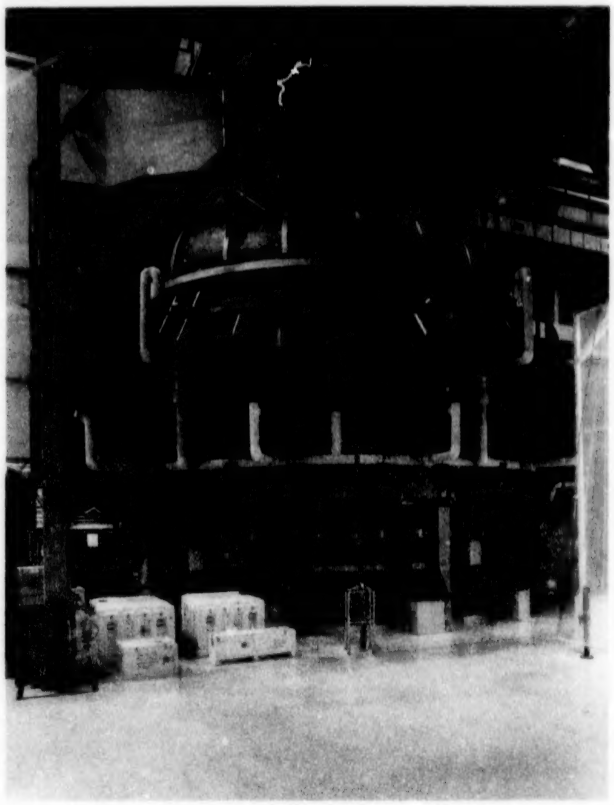


FACILITY 290 CONTROL MIMIC PANEL

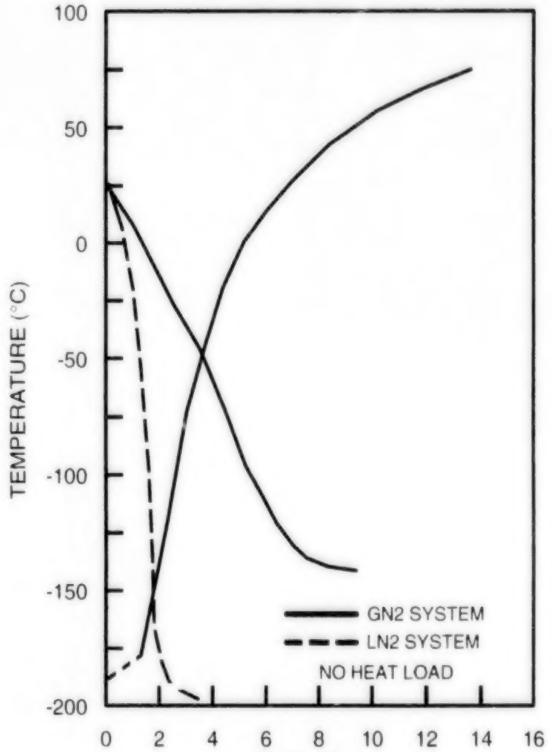


CHAMBER AND VACUUM SYSTEM SCHEMATIC
FACILITY 290

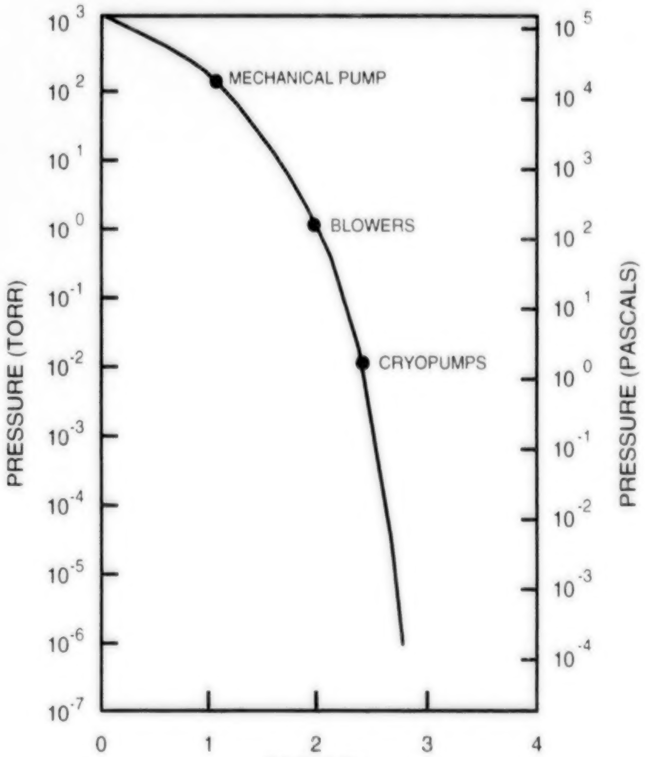
A918.011



CHAMBER VIEW



SHROUD TEMPERATURE PERFORMANCE



FAC. 290 PUMPDOWN

A918.012

3.6.4 SOLAR SIMULATORS, PORTABLE

3.6.4.1 61CM (24") - 1 S.C. SOLAR SIMULATOR (FACILITY 211)

DESCRIPTION: This portable solar simulator projects a divergent beam. The unit is mounted on a castered platform to provide alignment with the windows of the medium-sized thermal vacuum chambers. The power supply and controls are incorporated in a separate castered console.

MODE OF OPERATION: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured before the test article is installed in the facility. The lamp is then aligned at the quartz window at the required distance from the target plane. The lamp is ignited and the payload illuminated in accordance with the test procedure.

PARAMETERS:

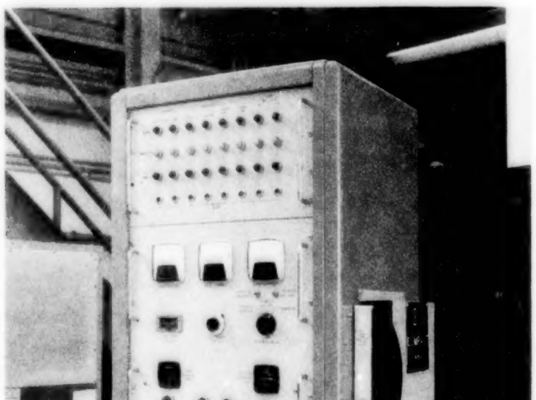
Beam size:	61cm (24") across flats	Intensity:	90 to 270 mw/cm^2 (0.16 in^2); 0.6 to 1.0 S.C.
Target plane:	191cm (75") from exit optics	Uniformity:	± 10% max of average intensity
Subtense angle:	7° half angle	Spectrum:	Filtered to air mass zero solar spectrum

PHYSICAL CHARACTERISTICS:

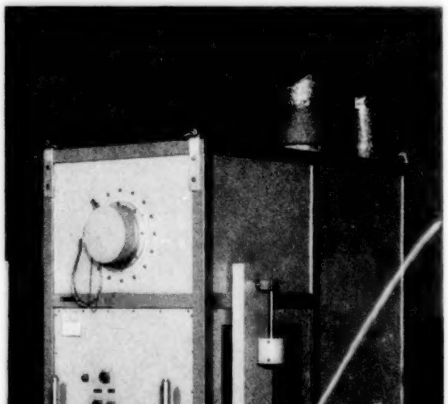
Source:	One 6.5 Kw xenon arc lamp	Utility requirement:	
Lamphouse:	76cm x 137cm x 122cm (30" x 54" x 48")	Power:	480V, 60Hz, 3 phase, 35amp; 110V, 60Hz, 1 phase, 25amp
Control console:	76cm x 76cm x 183cm (30" x 30" x 72")		
Platform:	173cm x 76cm x 127cm (68" x 30" x 50")	Cooling water:	15°C to 30°C (59°F to 86°F); 11 to 19 lit/min (3 to 5 gal/min)
Exhaust fan:	8.5 m^3/min (300 ft^3/min)		

INTEGRAL INSTRUMENTATION:

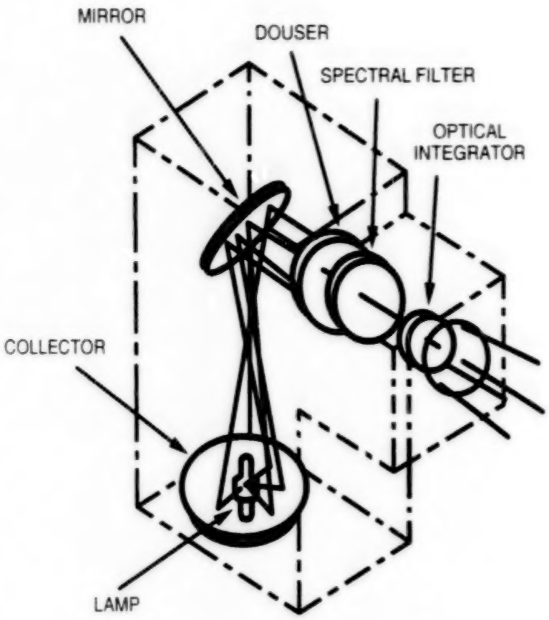
Lamp voltage:	0-150 VDC	Lamp intensity:	0-200 mw/cm^2 (0.16 in^2)
Lamp current:	0-200 amp DC	System alarms:	Klaxon and lights



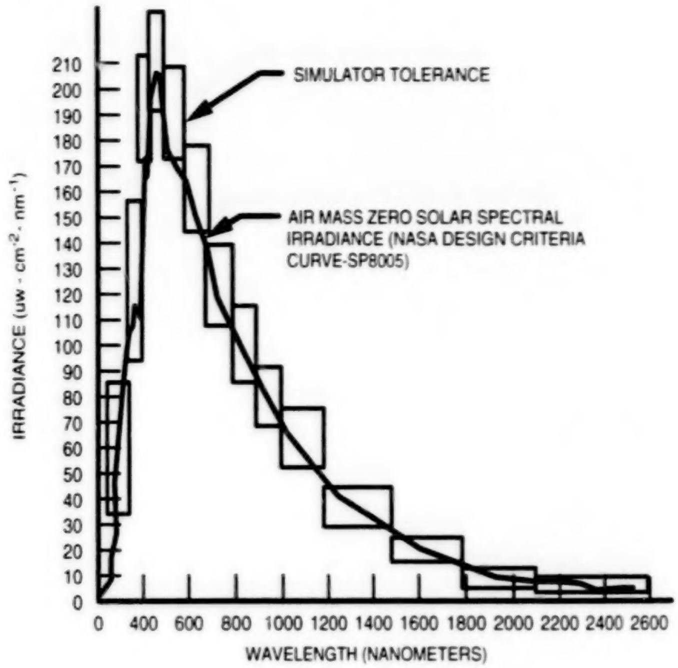
POWER SUPPLY



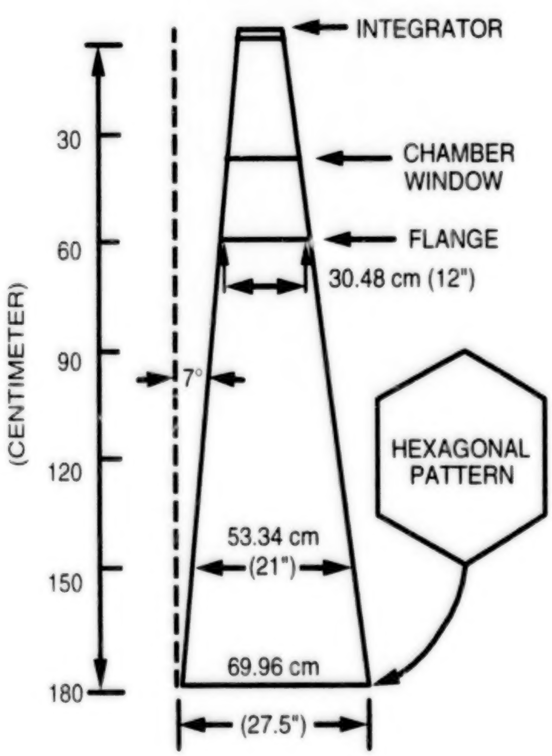
SOURCE MODULE



OPTICAL SCHEMATIC



SOLAR SIMULATOR SPECTRUM



BEAM SIZE OF SOLAR SIMULATOR

SPECTRAL BAND	NOMINAL ENERGY LEVEL (MW/CM^2)	DEVIATION (±%)
.25-.35	6.25	40
.35-.40	6.30	25
.40-.45	9.64	10
.45-.50	10.60	10
.50-.60	19.09	10
.60-.70	16.24	10
.70-.80	12.78	10
.80-.90	10.20	15
.90-1.0	8.07	15
1.0-1.2	12.30	20
1.2-1.5	11.25	20
1.5-1.8	6.10	20
1.8-2.2	4.50	30
2.2-2.5	1.99	30

SOLAR SIMULATOR SPECTRAL IRRADIANCE

A918.013

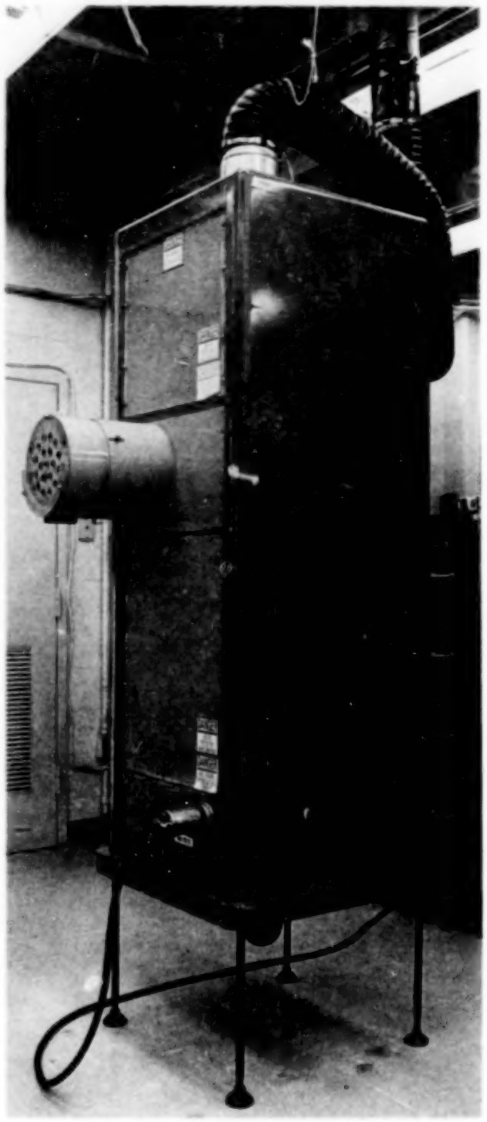
3.6.4.2 33CM (13") - 1 S.C. SOLAR SIMULATOR (FACILITY 213)

DESCRIPTION: This portable solar simulator incorporates the lamp, projection optics, power supply, and controls in a single castered cabinet. Power driven screw jacks at each corner permit raising the cabinet 61cm (24") to align the simulator with the chamber window.

MODE OF OPERATION: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured. After the payload is installed in the test facility, the lamp is aligned at the window at the required distance from the target plane. The lamp is ignited and the payload illuminated in accordance with the test procedure.

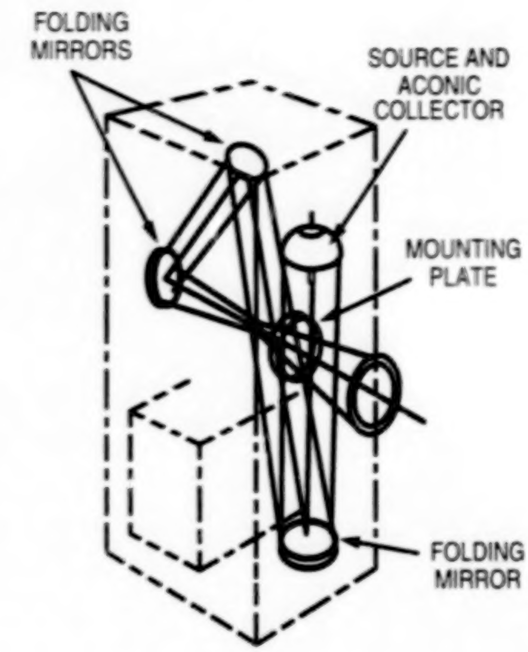
PARAMETERS:

Beam size:	33cm (13") across flats
Target plane:	55cm to 244cm (22" to 96") from exit optics
Subtense angle:	7° half angle
Intensity:	81 to 162 mw/cm^2 (0.16 in^2)
Spectrum:	Filtered to air mass zero solar spectrum
Uniformity:	± 5% max of average intensity as measured with a 1cm x 2cm (0.4" x 0.8") solar cell



PHYSICAL CHARACTERISTICS:

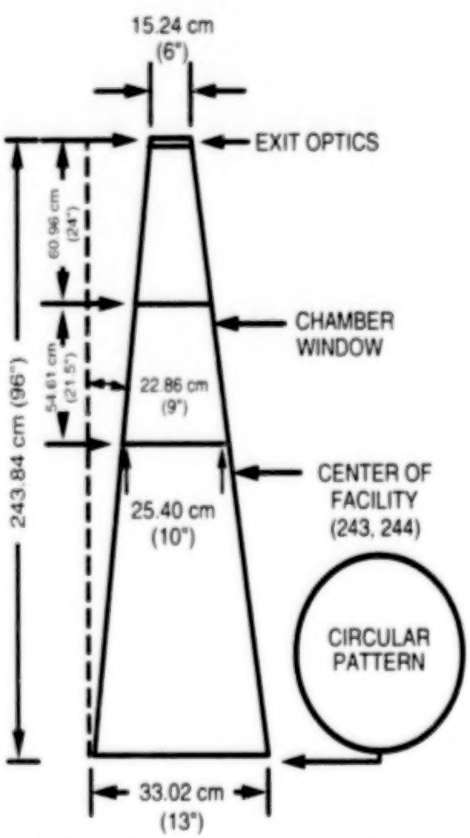
Source:	One 2.5Kw xenon arc lamp
Size:	58cm x 58cm x 213cm (23" x 23" x 84")
Power required:	480V, 60 Hz, 3 phase, 15 amp



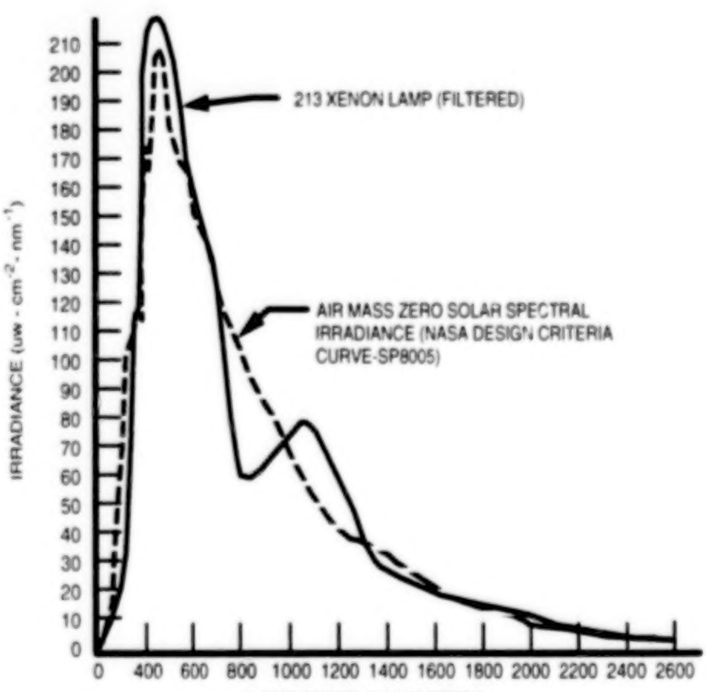
OPTICAL SCHEMATIC

SPECTRAL BAND	NOMINAL ENERGY LEVEL (MW/CM^2)	DEVIATION (±%)
.25-.35	7.80	40
.35-.40	11.80	20
.40-.45	19.00	10
.45-.50	21.80	10
.50-.60	19.00	10
.60-.70	15.00	10
.70-.80	11.50	10
.80-.90	6.00	15
.90-1.0	6.50	15
1.0-1.2	8.00	20
1.2-1.5	3.20	20
1.5-1.8	2.00	20
1.8-2.2	1.20	30
2.2-2.5	0.70	30

SOLAR SIMULATOR SPECTRAL IRRADIANCE



BEAM SIZE OF SOLAR SIMULATOR



SPECTRAL FILTERING EFFECTIVENESS

A918.014

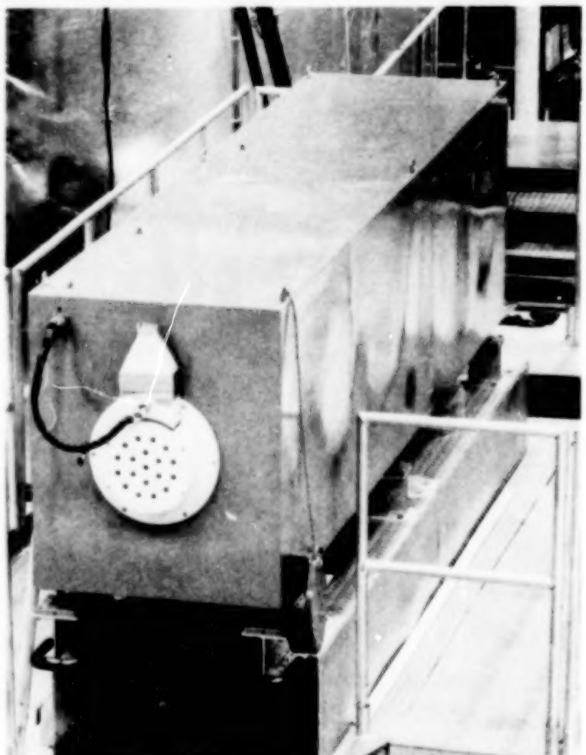
3.6.4.3 31CM (12") - 16 S.C; 102CM (40") - 1 S.C. SOLAR SIMULATOR (FACILITY 218)

DESCRIPTION: This portable solar simulator has two interchangeable projection systems. The facility is comprised of a lamp house with its optical projection system, a power supply console, coolant conditioning unit, and control console. The coolant conditioning unit provides high pressure, specially treated, de-ionized water to cool the lamp electrodes, primary reflector, negative lens holder, attenuators and dowser. The power supply provides the voltage and current to operate the lamp. The control console power/cooling units are centrally located, and the lamp console is portable.

MODE OF OPERATION: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured. After the payload is installed in the thermal vacuum chamber, the lamp is aligned at the window. The lamp is ignited and the payload illuminated in accordance with the test procedure. An integral dowser, which allows continuous lamp operation, is used for eclipses.

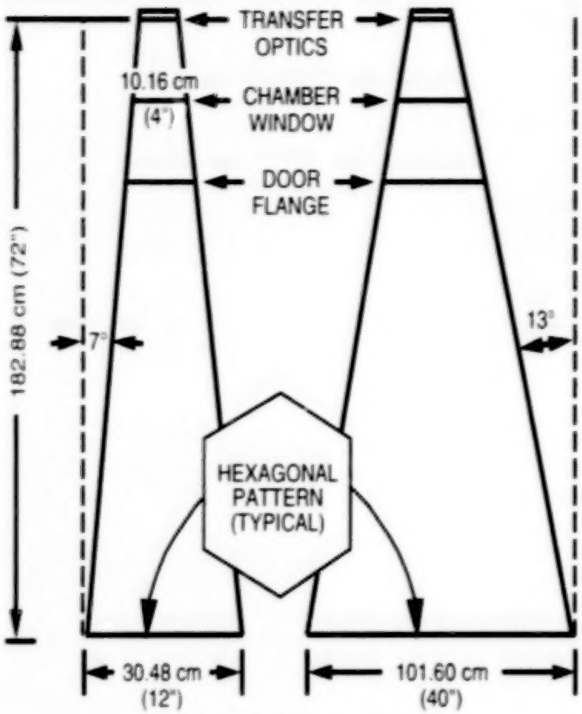
PARAMETERS:

Beam size:	31cm and 102cm (12" and 40") across flats
Target plane:	183cm (72") from exit optics
Subtense angle:	7° half angle (small beam)
	12.5° half angle (large beam)
Intensity:	
Small beam:	0.5 to 16 S.C. (filtered)
	0.5 to 25 S.C. (unfiltered)
Large beam:	0.5 to 1.0 S.C (filtered)
	0.5 to 1.5 S.C. (unfiltered)
Spectrum:	xenon or filtered to air mass zero
Uniformity:	± 5% max of average intensity

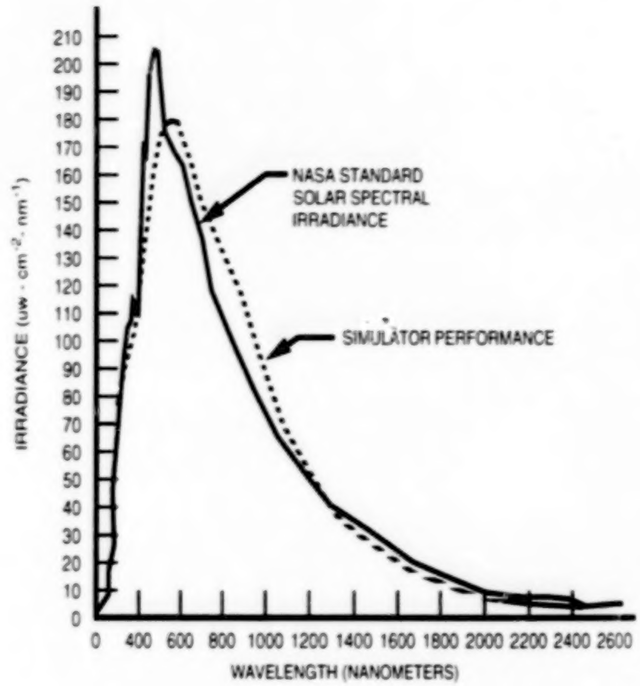


PHYSICAL CHARACTERISTICS:

Source:	One 20Kw or 32Kw xenon arc lamp
Utilities:	
Power:	480V, 60 Hz, 3 phase, 90 amp
	115V, 60 Hz, 1 phase, 20 amp
Cooling water:	414 to 552 Kpa (60 to 80 psi)
Air:	552 to 690 Kpa (80 to 100 psi)
GN_2:	690 Kpa (100 psi)



BEAM SIZE OF SOLAR SIMULATOR



SPECTRAL FILTERING EFFECTIVENESS

SPECTRAL BAND	NOMINAL ENERGY LEVEL (MW/CM^2)	DEVIATION (±%)
.25-.35	5.24	40
.35-.40	5.44	25
.40-.45	8.80	10
.45-.50	8.76	10
.50-.60	17.99	10
.60-.70	15.87	10
.70-.80	13.80	10
.80-.90	12.06	15
.90-1.0	10.96	15
1.0-1.2	12.31	20
1.2-1.5	8.73	20
1.5-1.8	5.45	20
1.8-2.2	3.32	30
2.2-2.5	1.29	30

SOLAR SIMULATOR SPECTRAL IRRADIANCE

A918.015

3.6.5 DATA ACQUISITION AND REDUCTION FACILITY

DESCRIPTION: This facility is a network of workstations designed to measure, display, and store data such as temperatures, chamber pressure, thermoelectric quartz crystal microbalance (TQCM) frequencies, voltages, and other data for the chamber and payload.

MODE OF OPERATION: The data system scans for facility and payload data every two minutes. Facility thermocouples are strategically placed to provide a full representation of all chamber shrouds. Monitoring stations for facility data are used by operators to accurately control transition rates and payload temperatures.

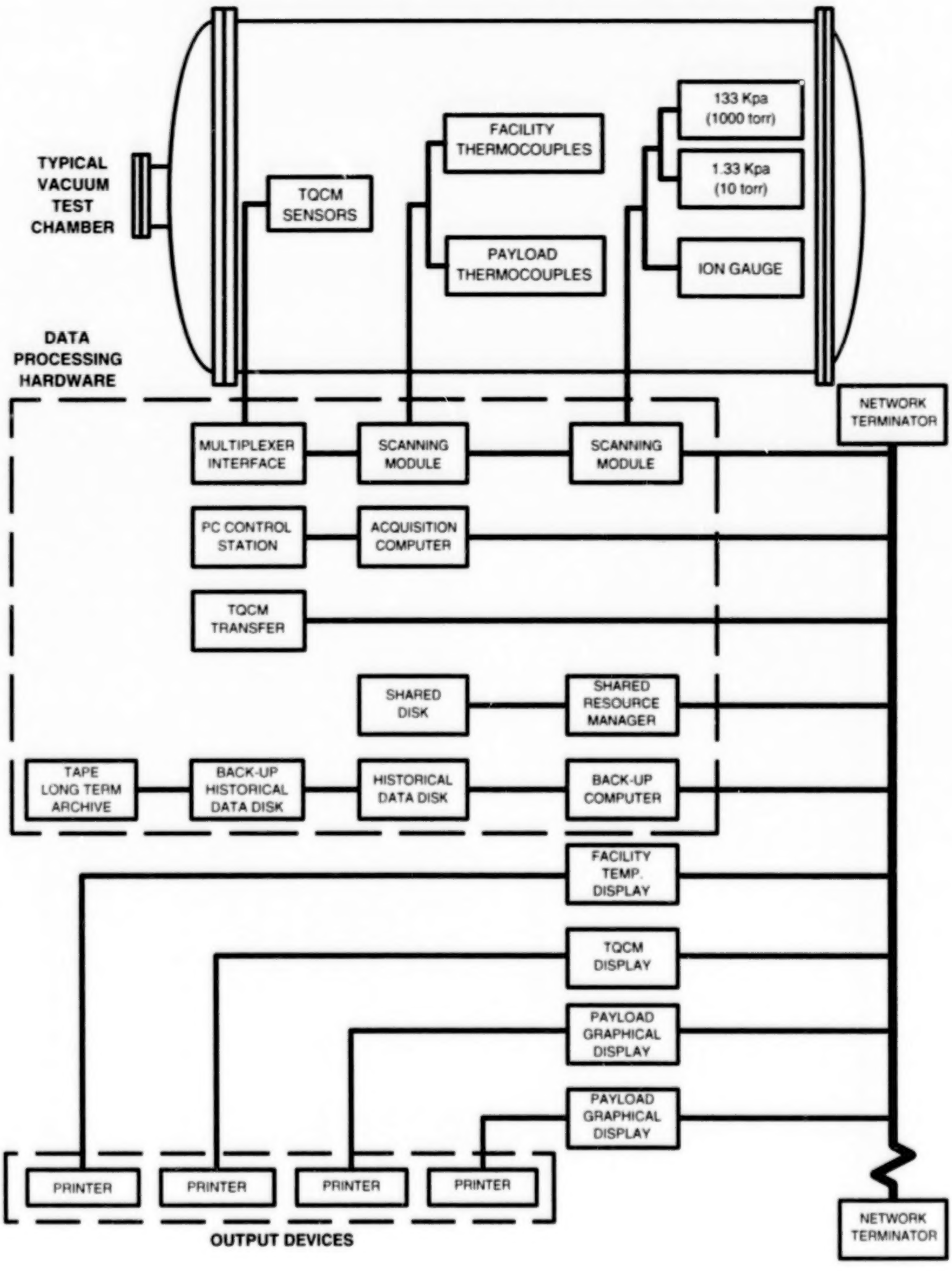
The number and location of payload thermocouples are determined by the experimenter/thermal engineer. A typical setup for the facility experimenter would include two monitors for tabular and graphical displays of payload data. The different operating parameters (temperature, pressure, TQCM frequencies, and rate of TQCM change) can be viewed simultaneously in tabular format or on a graphical plot versus time. All data is stored on the system's hard drives, and routinely archived onto a magnetic tape.

The data system operates as a 24-hour, stand-alone unit. The workstations and scanning modules are connected to an uninterruptible power supply to preclude loss of data in the event of a power outage. Hard copies of tabular and graphical test data are made at least on an hourly basis. Data can be transferred electronically to IBM-compatible floppy disks for use on personal computers.

SOFTWARE FEATURES: Software programs have been developed to provide the following features: Thermocouple group averaging and alarm limits are used extensively for facility and payload control. TQCM frequency, chamber pressure, and multiple channel temperature plots in the form of 1, 4, 8, and 12-hour intervals can be made at any time during the test. On-line access of up to two weeks of past TQCM data is available for instantaneous review.

INTEGRAL INSTRUMENTATION: Quicker scan times or customized test measurements can be accommodated via a portable acquisition station(s). Devices that produce a resistance, voltage, or digital output signal can be monitored as needed.

DATA ACQUISITION SCHEMATIC



A918.016

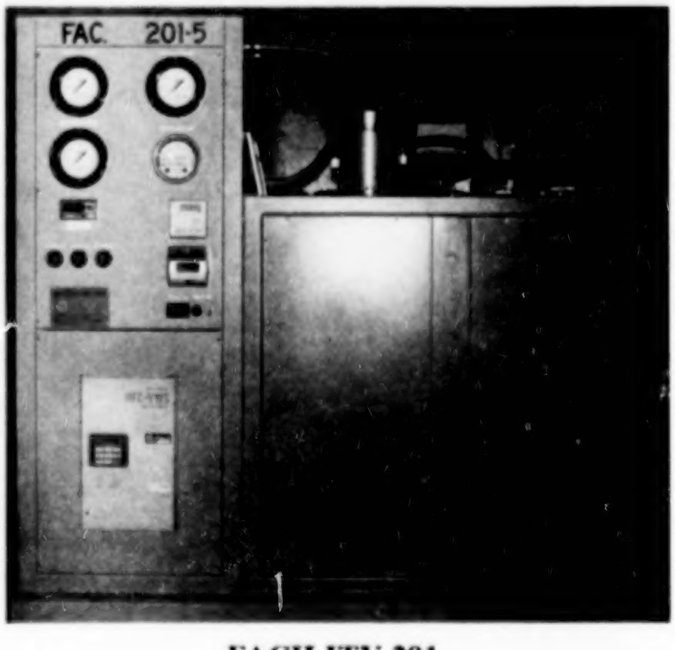
3.6.6 THERMAL CONDITIONING UNITS

DESCRIPTION: The following thermal conditioning units are portable and available for use at each thermal vacuum facility as needed. They are designed to produce and maintain a wide range of temperatures. The heat transfer medium is GN_2 for all units. Typical applications for these units include independent thermal control of test articles and contamination monitoring devices such as mirrors and TQCMs. Chamber penetrations are configured to accommodate the thermal conditioning units.

Facility No.	Temp Range	Heating Capacity (watt)	Cooling Capacity (watt)	Size (H x W x D)	MFR	Notes
201	-140 to +140 °C (-220 to +284 °F)	1,400	1,000	1.8m x 0.97m x 1.7m (5.9' x 3.2' x 5.6')	CVI	
205	-100 to +100 °C (-148 to +212 °F)	500	500	0.89m x 0.51m x 0.51m (2.9' x 1.7' x 1.7')	Slack	1
206	-140 to +100 °C (-220 to +212 °F)	500	500	1.8m x 1.2m x 0.91m (5.9' x 3.9' x 3.0')	Slack	2
207	-140 to +100 °C (-220 to +212 °F)	300	300	0.38m x 0.38m x 0.38m (1.3' x 1.3' x 1.3')	Slack	1

Note 1: Thermal capacities at nominal 10°C (18°F) gradient
Note 2: Thermal capacities at 34 Kpa (5 psi) payload circuit resistance

FACILITY 205



FACILITY 201

3.6.7 ELECTRICAL HEATER CONTROLLER (FACILITY 242)

DESCRIPTION: The electrical heater controller rack is a standard 48cm (19") electronic console which contains direct current/direct voltage power supplies, power distribution, and a microprocessor-based control panel. A total of 16 heater circuits can be controlled individually, at continuously variable temperatures between -100 and +100°C (-148 and +212°F). Power available for heater circuits is 5.4 Kw maximum. All adjustments are available from the front panel and can be locked against tampering. Each heater zone is alarmed.

MODE OF OPERATION: Each temperature control panel can control 16 heater circuit zones. The microprocessor-based panel uses a platinum resistance temperature detector (PRTD) to feed back real time temperature data. The panel uses a proportional plus reset plus rate characteristic to control a solid state relay. If the PRTD value exceeds the pre-set point, the solid state relay energizes and applies power to the heater. If the PRTD value is equal to, or lower than, the pre-set point, the solid state relay de-energizes and removes power from the heater.

PARAMETERS:

Temperature:	-100 to +100°C (-148 to +212°F)
Heater zones:	16 channels
Heater power:	5.4 Kw maximum

PHYSICAL CHARACTERISTICS:

Portable unit:	2.08m H x 0.61m W x 1.22m D (6.82' x 2' x 4')

3.6.8 RAPID PUMPDOWN SYSTEM (FACILITY 208)

DESCRIPTION: This high-speed vacuum pumpdown system is comprised of two rotary piston pumps manifolded in parallel to a chamber exhaust line. Two 2.1m x 2.4m (7' x 8') thermal vacuum chambers (one diffusion pumped, one cryopumped) are manifolded in parallel to the exhaust line providing rapid pumpdown. There is a foreline valve at the inlet of each pump, and a shut-off valve at each chamber. The pumps and valves are located in the basement and operated from a remote console.

MODE OF OPERATION: Each pump is started, and its ultimate pressure is verified to be less than 2.66 pascal (2×10^{-2} torr). The foreline valve and the valve at the required chamber are opened. When test pressure is achieved, the chamber valve is closed. The foreline valves are closed and the pumps are secured.

PARAMETERS:

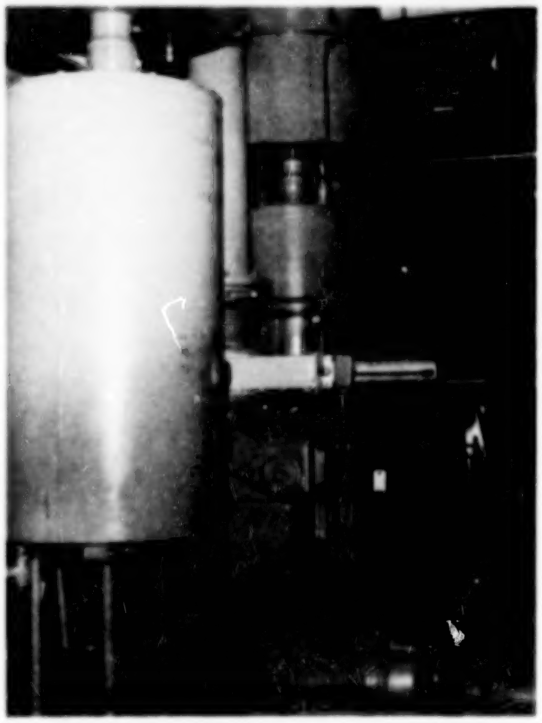
Ultimate pressure:	1.33 pa (10^{-2} torr)
Pump down time:	Either chamber - atm to 2.66 pa (2×10^{-2} torr) in 5 min.
Pump speed:	22m^3/min (780 ft^3/min) each pump

PHYSICAL CHARACTERISTICS:

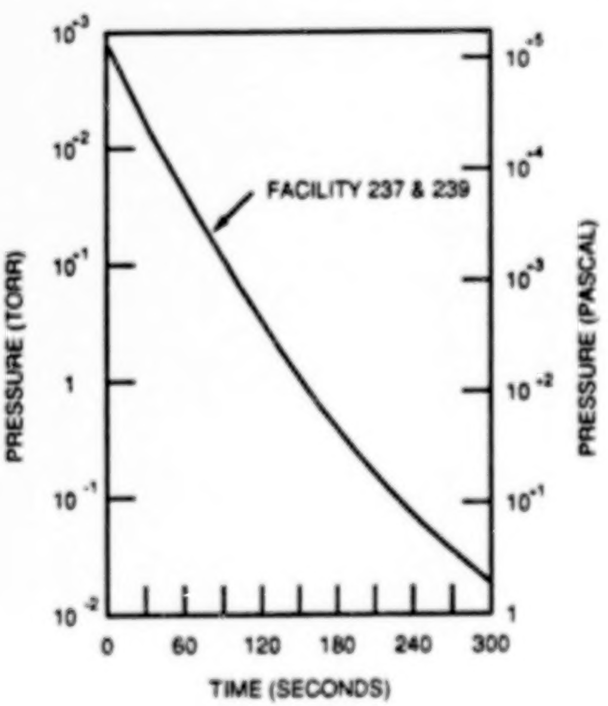
Foreline size:	25cm (10") diameter
Chamber manifold:	31cm (12") diameter

INTEGRAL INSTRUMENTATION:

Pump foreline pressure:	T/C gauge for atm to 0.13 pa (10^{-3} torr)



FACILITY VIEW



PRESSURE PROFILE

3.6.9 CONTAMINATION-FREE ROUGHING SYSTEM

DESCRIPTION: The Perkin-Elmer ULTEK contamination-free roughing system consists of a carbon vane oil-free blower working in conjunction with three stages of carbon sorption pumps. The pumps operate at liquid nitrogen temperatures. System operation is monitored with a pressure gauge (readout in torr) and a separate thermocouple gauge.

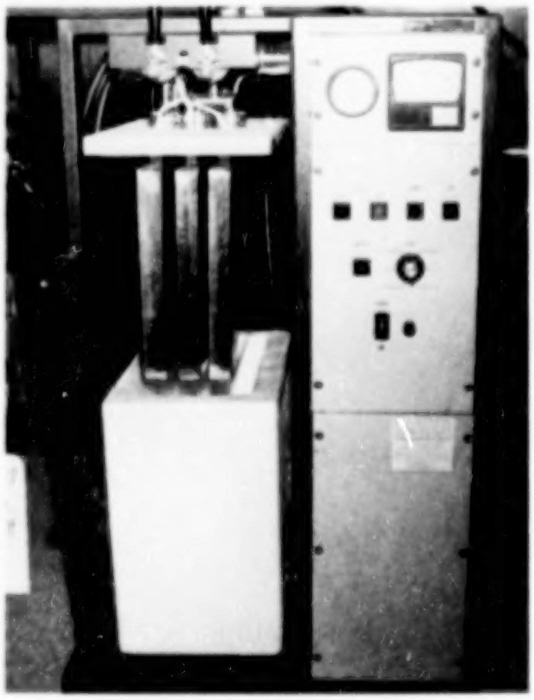
MODE OF OPERATION: The contamination-free roughing pump is connected to the vacuum system. The carbon sorption pumps are established at the liquid nitrogen temperature. At atmospheric pressure, the carbon vane oil-free blower is turned "ON" and the test volume pressure is reduced to 20 Kpa (150 torr). When the pressure has reached 20 Kpa, the first stage of sorption pumping is valved to the test chamber volume. By opening the sorption pump valve, the blower is automatically shut down. This first stage consists of two sorption pumps in parallel, and is capable of lowering the test chamber pressure to 66 pa (0.50 torr). At 66 pa (0.50 torr), the first sorption pumping section is secured, and the second, single section of sorption pumping is valved to the test chamber volume. The chamber pressure will reduce to 1.33 pa (10^{-2} torr) The test chamber is then isolated from the contamination-free roughing system, and an ion pump or cryopump would be used to establish hard vacuum.

PARAMETERS:

Ultimate pressure:	1.33 pa (10^{-2} torr)
Chamber volume:	650 liters (172 gal) maximum

INTEGRAL INSTRUMENTATION:

Thermocouple gauge, blower control, regeneration heater, LN_2 level control



3.6.10 CONTAMINATION MONITORING

3.6.10.1 RESIDUAL GAS ANALYZER (RGA)

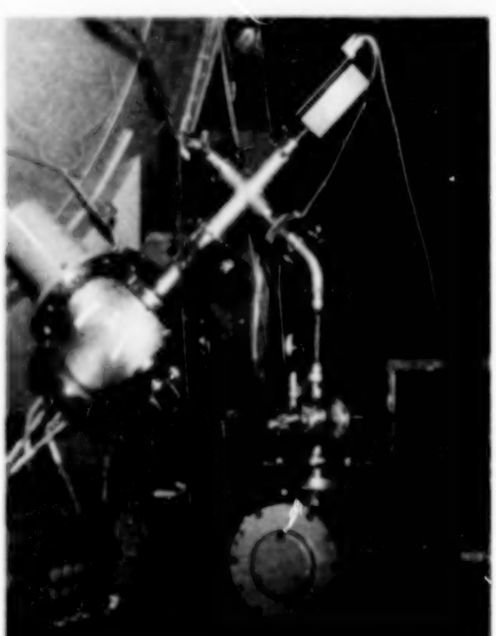
DESCRIPTION: The residual gas analyzer is used to measure the partial pressures of ionized molecules over a mass range of 1 to 300 atomic mass units (AMU). Using a combined RF and electrostatic field formed by two metal rods, the RGA scans the mass range and detects the partial pressures of each element or compound fraction.

MODE OF OPERATION: The RGA probe is located in the thermal vacuum facility and is oriented to maximize the detection of the outgassing species. After the facility pressure reaches 13.3 mpa (10^{-4} torr), the instrument may be activated. An alternate technique is to use the micro-sampling valve at high chamber pressure. Monitoring and recording of the vacuum environment is via a display meter and printer. The data can be stored and recalled at any time. An integrated programmable data system with dual disk drives allows flexibility in scanning, monitoring, storing, printing, and recalling the data.

PARAMETERS:

Make & Model	Faraday Cup	Electron Multiplier	AMU Range	Max. Operating Pressure	Min. Detectable Partial Pressure
UTI 100C	Yes	Yes	1-300	6.6 mpa (0.5×10^{-4} torr)	1.33×10^{-12} pa (10×10^{-15} torr)
MKS PPT-1A-100FC	Yes	No	1-100	13.3 mpa (1.0×10^{-4} torr)	1.33×10^{-9} pa (10×10^{-12} torr)
Leybold C100F	Yes	No	1-100	13.3 mpa (1.0×10^{-4} torr)	6.7×10^{-9} pa (50×10^{-12} torr)

Note: Two auxiliary RGA manifolds are available, with appropriate valves, that provide sampling of chamber gasses when chamber pressure is between 13.3 mpa (10^{-4} torr) and atmosphere.



3.6.10.2 THERMOELECTRIC QUARTZ CRYSTAL MICROBALANCE

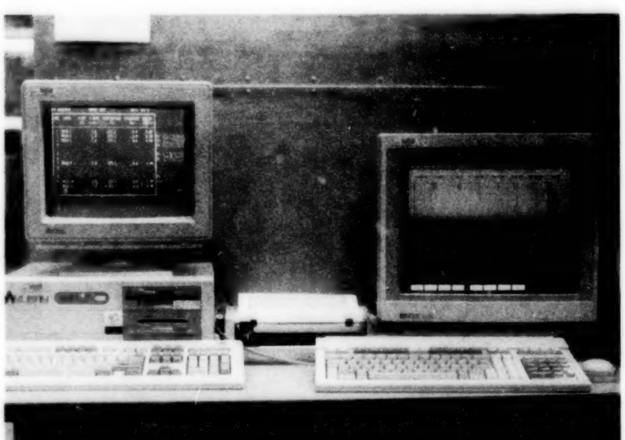
DESCRIPTION: The thermoelectric quartz crystal microbalance (TQCM) and M-2000 control unit system measures and records condensable masses which deposit on a piezoelectric crystal. Extreme accuracy is obtained by comparing the exposed measurement crystal to a matched encapsulated reference crystal located in the same TQCM head. A computer controlled thermoelectric pump provides a high degree of crystal temperature control, which is vital for accurate frequency measurement. Two TQCM sensing units may be used, 10 MHz or 15 MHz. All relevant data is sent from the M-2000 control unit and the PC control station to the data acquisition and reduction facility.

MODE OF OPERATION: One or more TQCM sensing units are installed in a thermal vacuum chamber. The chamber is pumped down to a test pressure of 1.33 mpa (10^{-5} torr) or less, at which point the TQCM is turned on and set for the appropriate operating temperature. As the payload outgasses and materials condense on the TQCM sensing crystal, the crystal frequency increases directly proportional to the amount of payload outgassing.

PARAMETERS:

Mass sensitivity:	4.43×10^{-9} g/cm²-Hz (1.01×10^{-9} oz/in²-Hz) for the 10 MHz unit
	1.97×10^{-9} g/cm²-Hz (0.45×10^{-9} oz/in²-Hz) for the 15 MHz unit
Crystal temperature:	-50 to +100°C, ± 0.1°C (-58 to +212°F, ± 0.18°F)
Sensor unit size:	5cm (2") diameter x 25.5cm (10") L with heat sink lines

INTEGRAL INSTRUMENTATION: The instrument consists of a TQCM sensor head unit, M-2000 multichannel control unit, PC control station, and heat sink temperature control system.



TQCM COMPUTER CONTROL

TQCM ACQUISITION UNIT

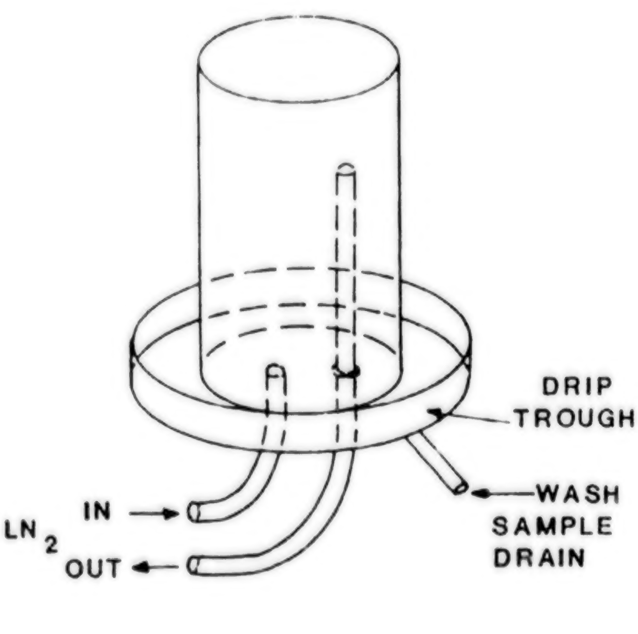
3.6.10.3 COLD FINGER (C/F)

DESCRIPTION: Cold fingers are small stainless steel cylinders which are mounted in the test volume of each thermal vacuum chamber. Condensable vapors are collected by the cold finger and analyzed after the test. In some cases, a large cold plate is used to collect the condensable materials. The cold finger is maintained at LN_2 temperature during test and until the chamber is backfilled to 80 Kpa (600 torr).

MODE OF OPERATION: The cold finger is thoroughly cleaned before the test. After the thermal vacuum test, the cold finger is warmed and again rinsed with isopropyl alcohol. The rinse sample is collected in a clean bottle and sent to the Materials Assurance Branch for quantitative and qualitative analyses.

PARAMETERS:

Size:	5cm (2") diameter x 7.6cm H (3")
Surface area:	$142cm^2$ ($22 in^2$) nominal
Temperature:	-196°C (-321°F)



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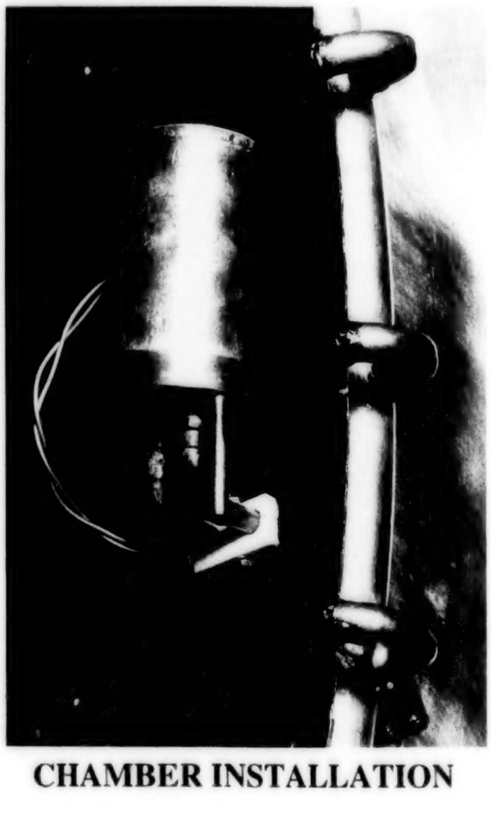


CHAMBER INSTALLATION

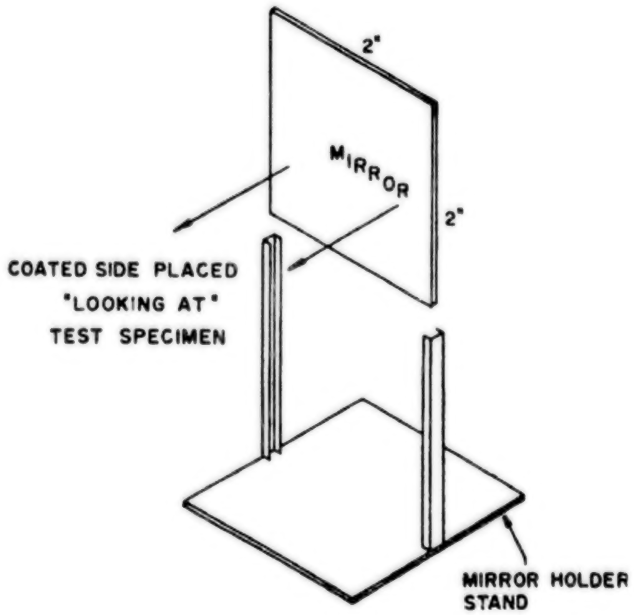
3.6.10.4 CONTAMINATION CONTROL MIRROR

DESCRIPTION: These aluminum coated mirrors are used primarily to collect outgassed materials in the thermal vacuum chambers; however, they may be placed anywhere to collect condensable matter. To determine the quantity of material on the mirror, reflective ultraviolet measurements are made prior to test, and then compared to post test measurements for a loss of reflectivity.

MODE OF OPERATION: The mirror is placed in the thermal vacuum chamber (or other environment) and allowed to remain in that location for the duration of the test. In most cases, the mirror's temperature follows the thermal vacuum chamber temperature profile; however, the mirror's temperature can be controlled if desired. For large accretions (greater than 10% change in reflectivity) the mirror is sent to the Materials Assurance Branch for chemical analysis of the non-volatile residue.

PARAMETERS:

Temperature:	-190 to +100°C (-310 to +212°F)
Measurement error:	± 2%
Measurement wavelength:	1216Å, 1608Å, and 2000Å
Mirror size:	5cm x 5cm (2" x 2"), coated on one side
Coating:	Al - 600 to 800Å thick
Over coating:	MgFl - 250Å thick



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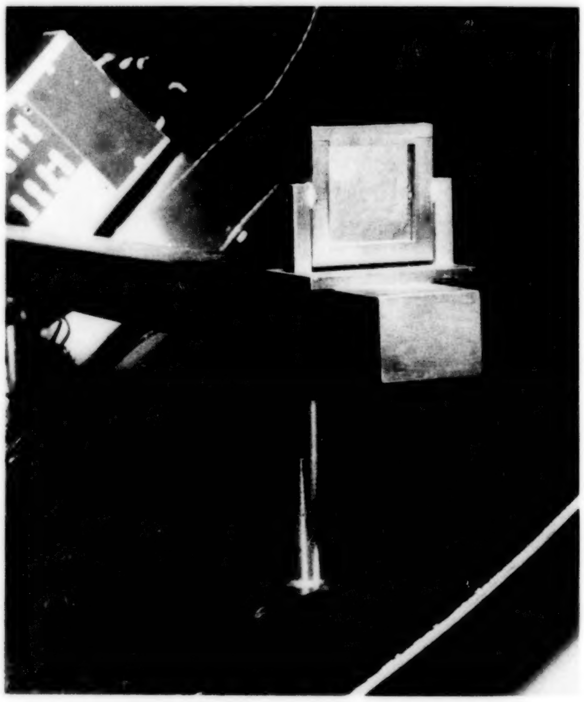
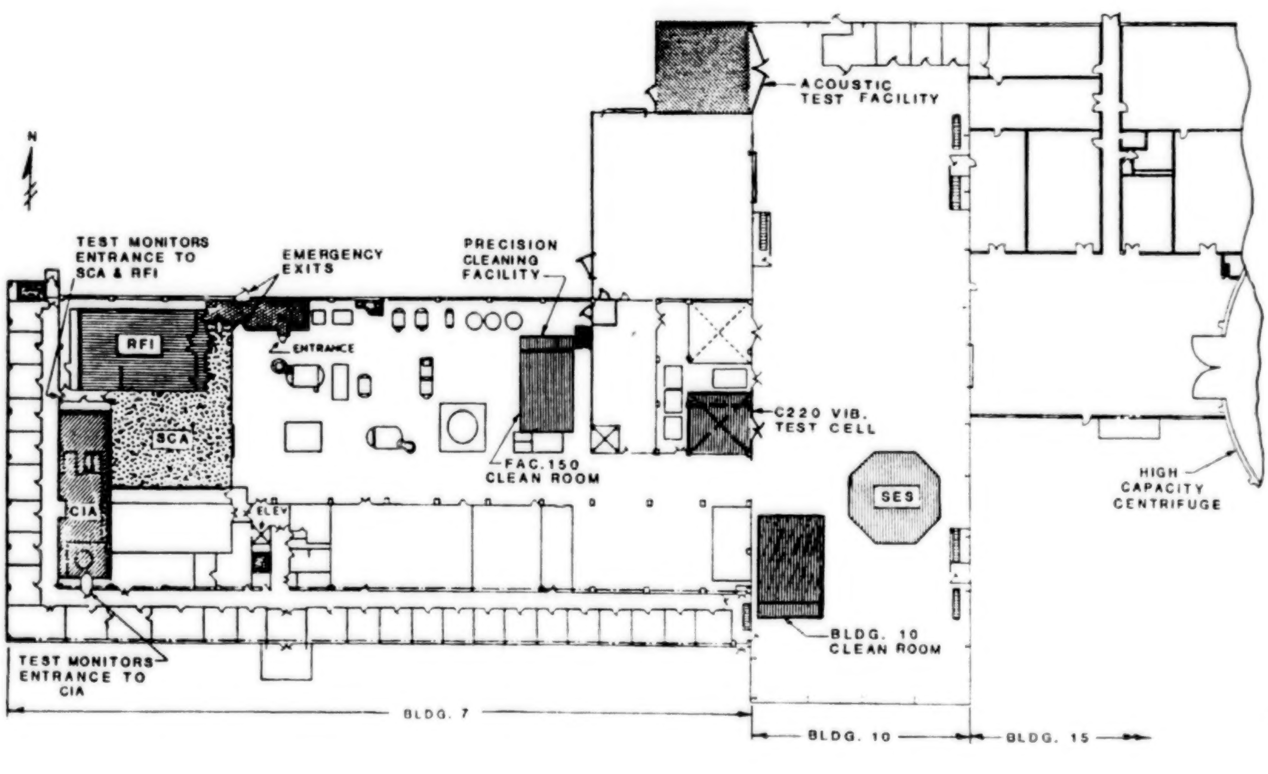


CHAMBER INSTALLATION

3.7 CLEANROOMS

DESCRIPTION: Code 750 cleanrooms are designed and operated to maintain a classification of air cleanliness by introducing air into the room, tent, or bench with conditioned recirculatory or direct ambient air systems through a series of high efficiency (HEPA) air filters. The filtered air is maintained at specified velocities in a unidirectional flow pattern that causes contaminants generated within the facility to be carried away in the direction of the moving air stream.

MODE OF OPERATION: Cleanrooms are monitored on a periodic basis to verify that the classification of the facility remains within specification. Cleaning is performed on a predetermined or "as required" schedule based on classification monitoring results. Used cleanroom garments are continuously removed from the change rooms and replaced with fresh packaged garments. Project personnel are present inside the cleanrooms during test activity to insure that proper cleanroom procedures are followed.



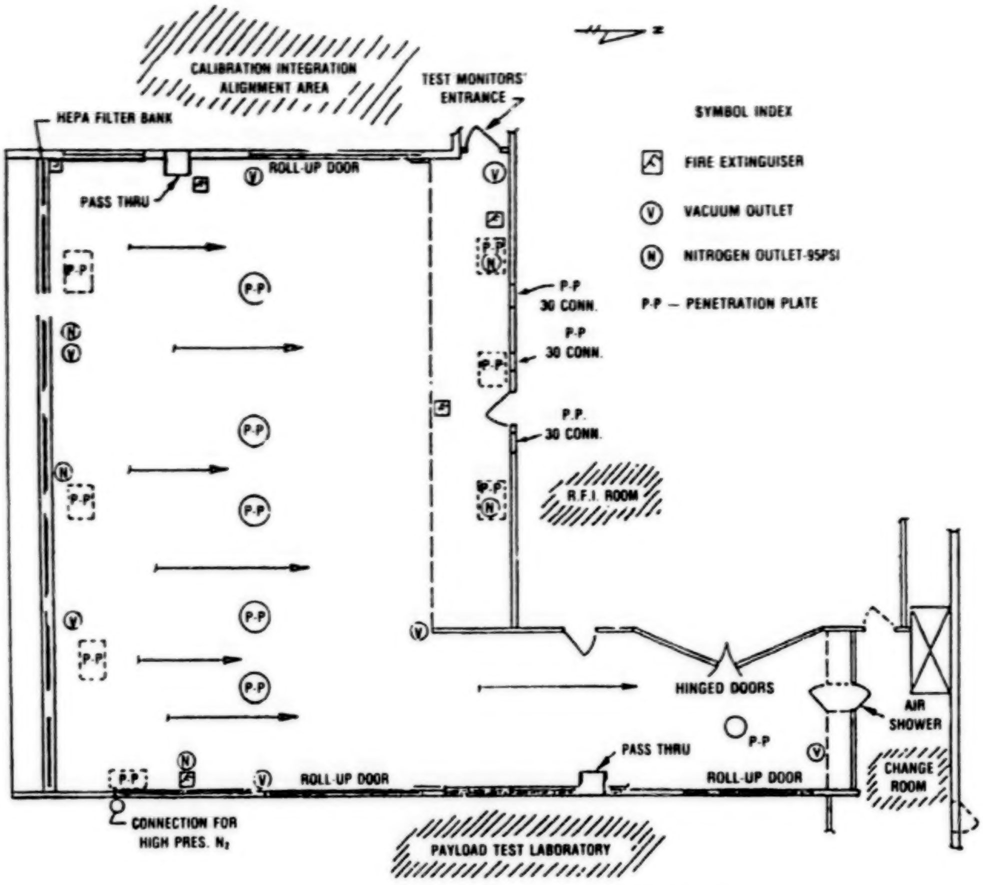
BUILDINGS 7, 10, & 15 CLEAN ROOM LOCATIONS

3.7.1 SPACECRAFT CHECKOUT AND INTEGRATION AREA (SCA)

SIZE	17m L x 11m W x 10m H (56' x 36' x 33')
SOUTH WALL FILTER BANK	5,664 m^3/min (200,000 ft^3/min) - horizontal flow
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	21 ± 3 °C (70 ± 5 °F)
RELATIVE HUMIDITY	44 ± 4%
ENTRANCE (HARDWARE)	Rollup door: 5.9m W x 6.0m H (19.4' x 19.7')
CLEANLINESS	Class 10,000 (M5.5)
OTHER SERVICES	electrical, compressed dry nitrogen, under-floor cable tray system, telephone and intercom, outlets for central vacuum
OTHER PARAMETERS	RF shielded short arc mercury lamps in the ceiling provide general lighting. The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The concrete floor has a polyurethane coating.

3.7.2 RFI SHIELDED ROOM

SIZE	18m L x 11m W x 6m H (59' x 36' x 19.7')
WEST WALL FILTER BANK	1,982m^3/min (70,000 ft^3/min) - horizontal flow
AIR VELOCITY	30m/min (100'/min), minimum
TEMPERATURE	21 ± 3 °C (70 ± 5 °F)
RELATIVE HUMIDITY	44 ± 4%
RF WAVE GUIDES	at entrance and exit
ENTRANCE (HARDWARE)	double door: 6.1m W x 5.8m H (18.5' x 17.9')
CLEANLINESS	class 10,000 (M5.5)
OTHER PARAMETERS	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The floor has a polyurethane coating.



SCA & RFI SHIELDED ROOMS

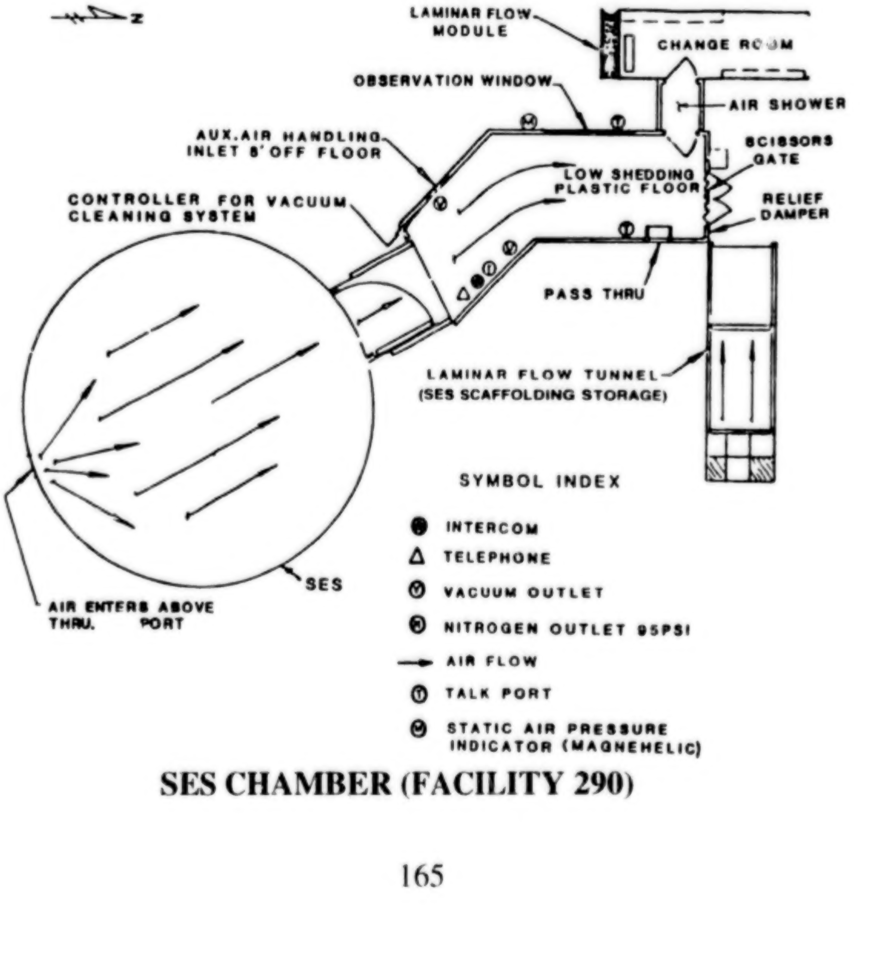
3.7.3 MB C220 VIBRATION TEST CELL

SIZE	**8.8m L x 8.2m W x 15.5m H (29' x 27' x 51')**
CEILING MOUNTED FILTER BANK	**1,416m^3/min (50,000 ft^3/min) - vertical flow**
AIR VELOCITY	**19.8m/min (65'/min), minimum**
TEMPERATURE (NOMINAL)	**22.8 °C (73 °F)**
RELATIVE HUMIDITY	below 50%
PASS THROUGH WINDOW	basement level
PERSONNEL ENTRY	basement level through NE corner
CLEANLINESS	class 10,000 (M5.5)
OTHER SERVICES	electrical, telephone and intercom, compressed dry nitrogen, and outlets for a central vacuum system
OTHER PARAMETERS	To minimize particle generation, the walls and exposed steel have been painted with epoxy paint and the floor has been coated with torginol seamless quartz flooring.

3.7.4 SPACE ENVIRONMENT SIMULATOR (SES)

PRE-PUMPDOWN SPECIFICATIONS

VACUUM CHAMBER SIZE	8.2m (27') diameter x 12.2m H (40')
AIR FLOW	$283 m^3$/min (10,000 ft^3/min)
TEMPERATURE (NOMINAL)	22.8 °C (73 °F)
RELATIVE HUMIDITY	below 60%
ANTEROOM	7.6m L X 3.1m W (25' x 10')
AIR FLOW	$28.3 m^3$/min (1,000 ft^3/min)
EAST WALL	small parts passageway
NORTHWEST CORNER	change room and air shower
CLEANLINESS	class 10,000 (M5.5)
OTHER SERVICES	electrical, compressed dry nitrogen, outlets for the central vacuum cleaning system
OTHER NOTES	When the chamber door is open and the chamber clean air supply is on, air flows out of the chamber, down the length of the anteroom, and out through a louvered duct at the north end. When chamber door is closed, a small auxiliary blower/filter unit supplies filtered air to the anteroom.



SES CHAMBER (FACILITY 290)

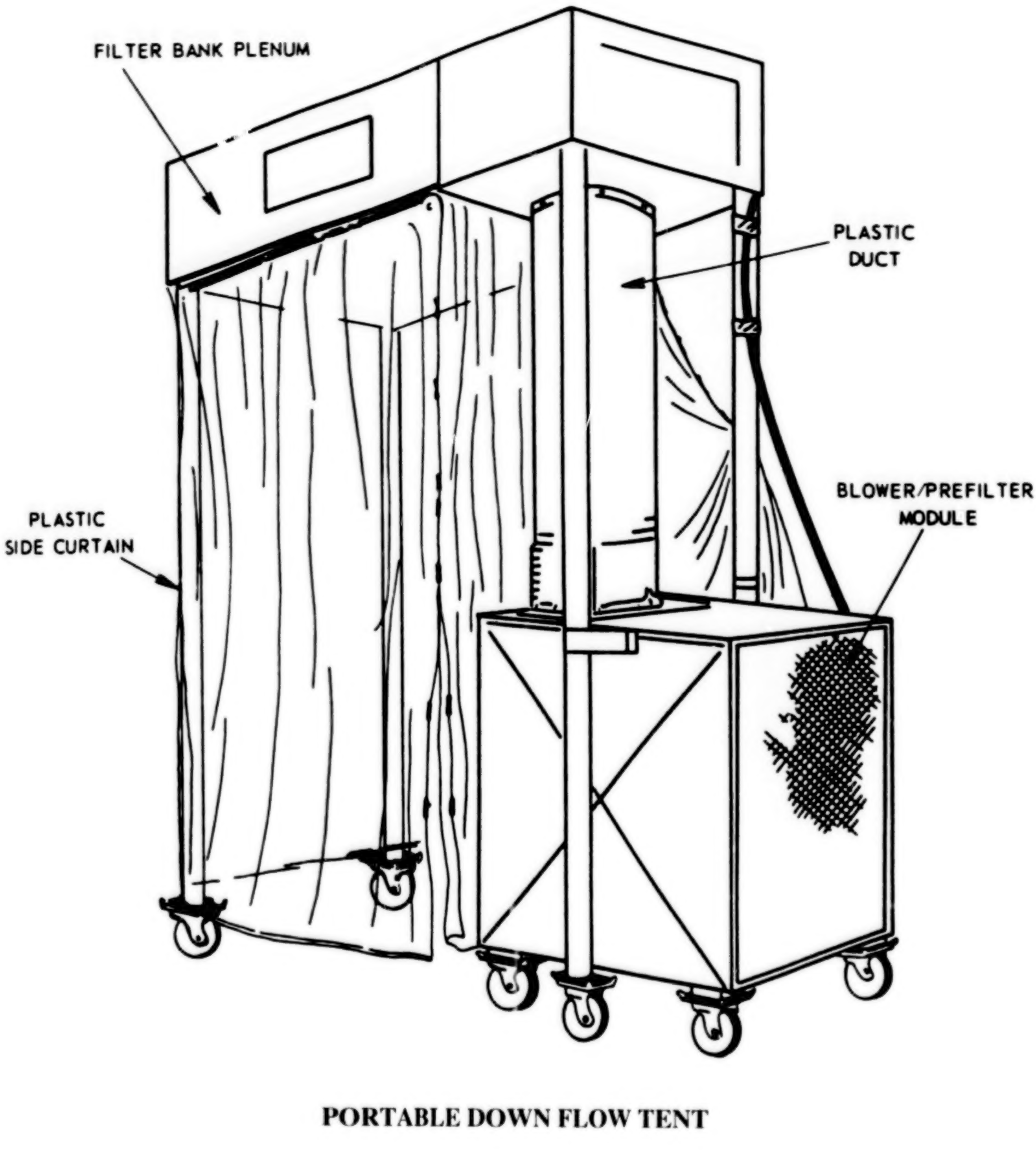
3.7.5 CLEANROOM TENTS

BUILDING 7 HIGH BAY	
SIZE	6.1m W x 9.1m L x 4.7m H (20' x 30' x 15.4')
AIR FLOW	1,303m^3/min (46,000 ft^3/min) - vertical
CLEANLINESS	class 10,000 (M5.5)
CRANE	227 Kg (500 lb) hoist
AIR VELOCITY	31m/min (100'/min)
ENTRANCE	6.1m W x 4.7m H (20' x 15.4') roll up curtain
TENT MATERIAL	anti-static polyethylene
TEMP/HUMIDITY	Building 7 HVAC

BUILDING 10 HIGH BAY	
SIZE	11.3m W x 5.5m L x 4.9m H (37' x 18' x 16')
AIR FLOW	1,869m^3/min (66,000 ft^3/min) - horizontal
CLEANLINESS	class 10,000 (M5.5)
AIR VELOCITY	31m/min (100'/min)
ENTRANCE	5.5m W x 4.9m H (18' x 16') roll up curtain
TENT MATERIAL	305 micron (12 mil) PVC
TEMP/HUMIDITY	Building 10 HVAC

3.7.6 PORTABLE DOWN FLOW TENTS

PORTABLE DOWN FLOW TENTS	
SIZE	1.22m W x 2.44m L x 3.66m H (4' x 8' x 12')
CLEANLINESS	class 10,000 (M5.5)
TEMPERATURE	not controlled
HUMIDITY	not controlled
SUPPORT	free standing
OTHER NOTES	Tents can be interlocked to form a 2.44m W x 2.44m L (8' x 8') module. They have side curtains of PVC or anti-static nylon, and can be floor mounted or have self-contained blower units and fluorescent lighting.



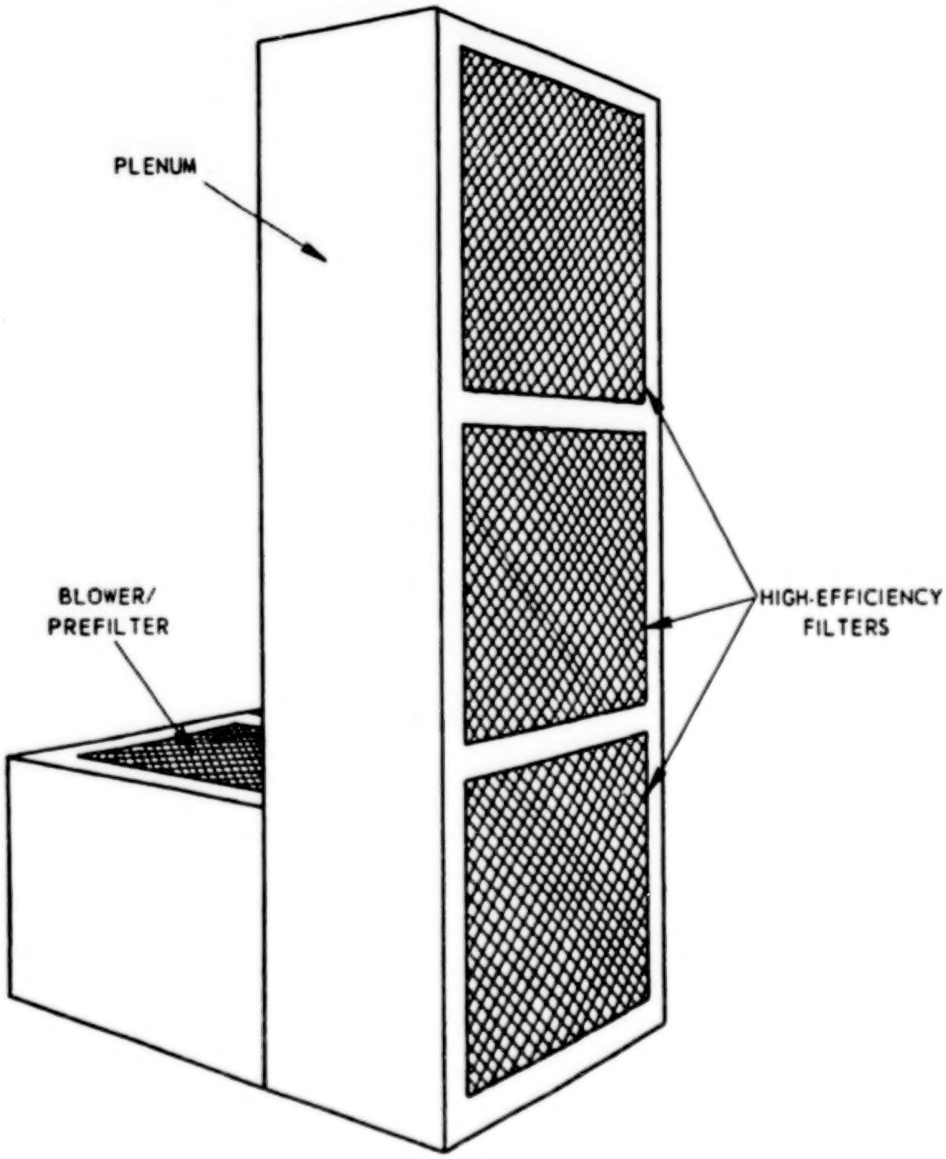
PORTABLE DOWN FLOW TENT

3.7.7 PORTABLE HORIZONTAL UNIDIRECTIONAL FLOW MODULES

To provide temporary horizontal unidirectional flow clean air, the ESD has six free standing horizontal unidirectional flow modules, 0.61m (2') wide and 1.83m (6') high, and two modules 1.83m (6') wide and 3.05m (10') high. Usually, a tunnel or other constraining boundary must be erected to use these modules. These modules have no air cooling or humidifying capability.

3.7.8 UNIDIRECTIONAL FLOW CLEAN BENCH

Several unidirectional flow clean benches are available. The working areas range from 1.22m (4') wide, 0.61m (2') deep, and 0.61m (2') high, to 1.52m (5') wide, 0.91m (3') deep, and 0.91m (3') high. The entire back wall of the clean bench is a high efficiency filter through which air passes at 31m/min (100'/min). The unit has no air conditioning or lighting. These benches can be maintained at an air cleanliness classification of class 100 (M3.5).



PORTABLE HORIZONTAL UNDIRECTIONAL FLOW MODULE

3.7.9 PORTABLE PARTICLE COUNTERS

The ESD has four $0.028m^3$/min ($1.0 ft^3$/min) and two $0.0028m^3$/min ($0.1 ft^3$/min) portable automatic particle counters. The particle counters can be used for certifying cleanrooms and other cleanroom devices.

3.7.10 PRESSURE, TEMPERATURE AND HUMIDITY MONITORING

Provisions have been made to monitor room air pressure, temperature, and humidity in the CIA, SCA, RFI, and MB C220 vibration test cell. Each area is equipped with temperature and humidity chart recorders and a Magnehelic differential pressure gauge. These are direct reading instruments whose displays are monitored by viewing them near the front windows of the cleanrooms.

3.7.11 CONTAMINATION MONITORING AND ANALYSIS LAB

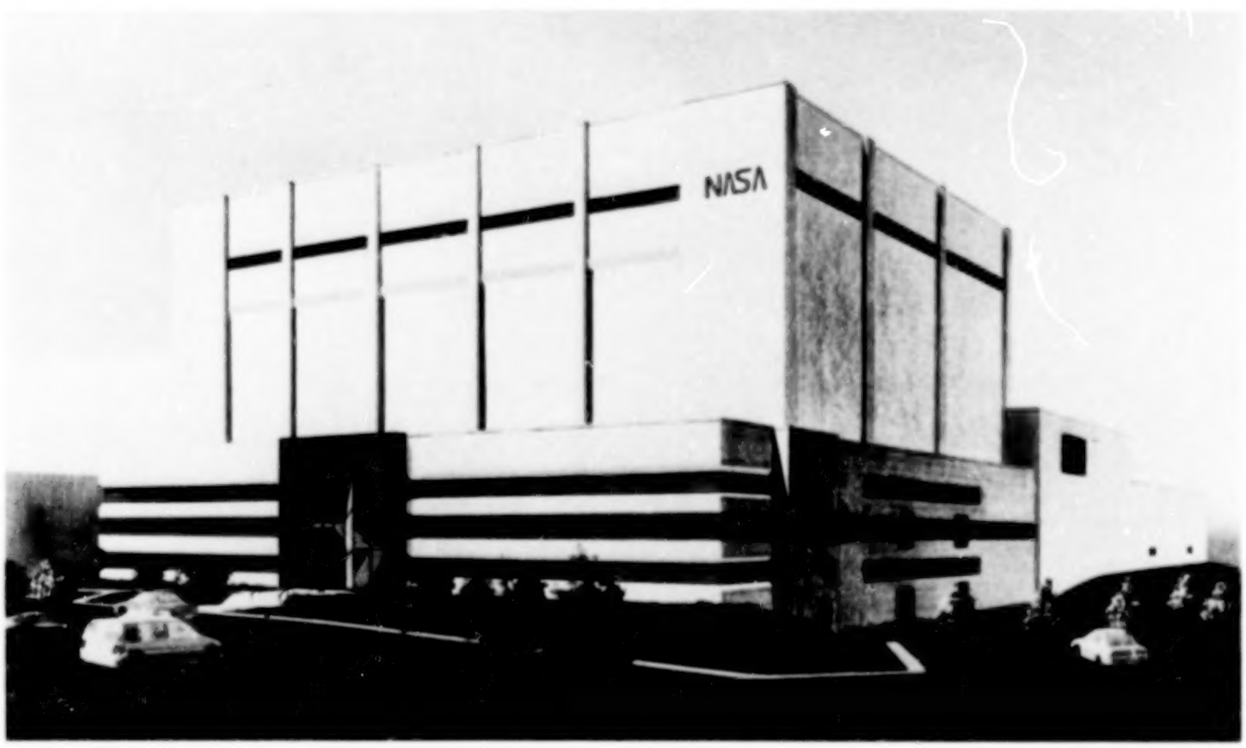
The Contamination Monitoring and Analysis Laboratory is located in the SSDIF Precision Cleaning Room. The lab is equipped with microscopes and an image analysis system for qualitative and quantitative analyses. A typical sample is taken to the lab in a clean container, the container is opened in the cleanroom, and the sample is placed under a microscope for a particulate count. When identification of the particles is required, the sample is studied using the image analysis system or the polarizing light microscope. Photographs may be taken and saved. After the contaminant has been identified, it can be traced to its origin, and steps can be taken to eliminate the source.

3.7.12 BUILDING 7, PRECISION CLEANING FACILITY (PCF)

The Building 7, Precision Cleaning Facility is a 2.44m x 4.88m x 3.05m high (8' x 16' x 10'), down flow modular cleanroom designed to clean and inspect items that require critical cleaning and inspection procedures. The facility is located adjacent to the Building 7, 150 tent, and contains pass through windows for moving equipment and parts from the PCF into the 150 tent. The PCF is equipped with a vented work bench for solvent cleaning and all the necessary apparatus to clean to level 100 (MIL STD 1246).

3.7.13 SPACECRAFT SYSTEMS DEVELOPMENT AND INTEGRATION FACILITY (SSDIF), BUILDING 29

DESCRIPTION: The SSDIF is a 7,989 m^2 (86,000 ft^2) facility designed to provide support for the integration and testing of spacecraft hardware. It is unique in the fact that it contains a 36,816m^3 (1.3M ft^3) horizontal, unidirectional flow cleanroom. Additional features include: Automated Data Processing Area, Shipping/Receiving Area, Flight Hardware Storage Area, and Precision Cleaning facilities.

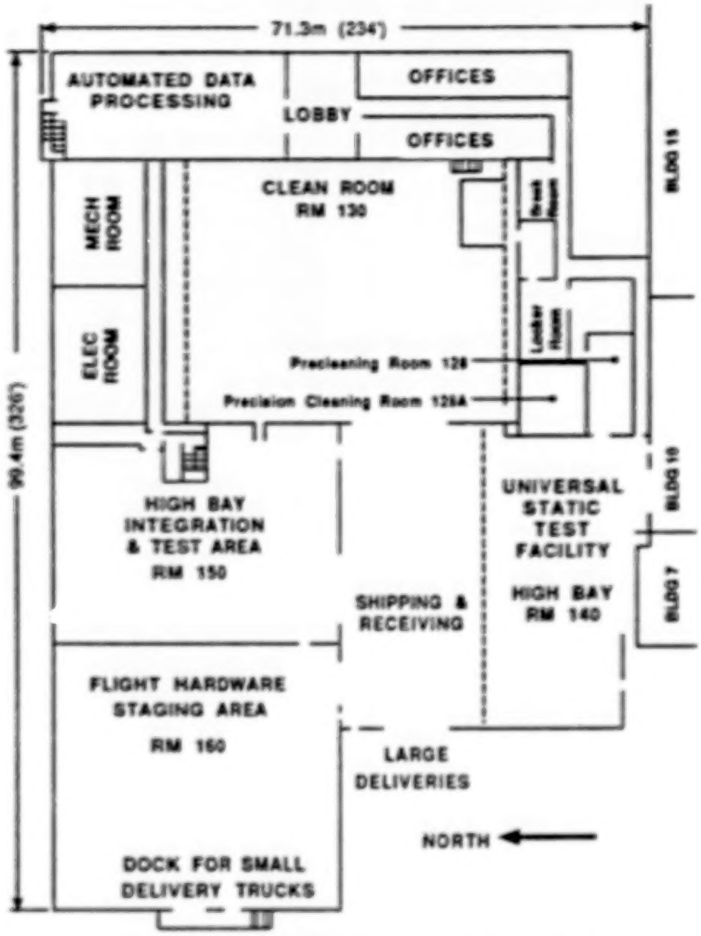


SSDIF HIGH BAY CLEANROOM

DESCRIPTION: The High Bay Cleanroom is a 1,161m^2 (12,500 ft^2), class 1,000 (M4.5), horizontal unidirectional flow cleanroom. It has been designed to support the integration and testing of flight hardware and has the capacity to accommodate two full-sized shuttle payloads simultaneously. A cable tray provides data cable access to the Automated Data Processing Room. Access to the cleanroom is via a 7.6m x 12.2m (25' x 40') overhead roll up door. Two 31,752Kg (35 ton) cranes, with hook heights of 21.0m (69') and 24.4m (80'), provide lift and transport capabilities. Materials of construction have been selected, and procedures designed, to minimize molecular and particulate contamination levels within this facility.

MODE OF OPERATION: A computer-based automatic control system monitors and controls environmental parameters on a 24-hour basis. Only approved personnel and materials are allowed to enter the cleanroom, and procedures are strictly enforced to maintain cleanliness of the facility. On-site contamination control personnel provide cleanroom support services such as: certification, monitoring, facility cleaning, maintenance of the change room, and precision cleaning.

SIZE	38m L x 31m W x 27m H (125' x 100' x 89')
CLEANLINESS: CLASS 1,000 (M4.5)	automatic real time monitoring
AIR VELOCITY	31m/min (100'/min), minimum
TEMPERATURE	18.3 to 23.9 °C (65 to 75 °F)
RELATIVE HUMIDITY	44 ± 4%
ENTRANCE (HARDWARE)	roll up door: 7.6m W x 12.2m H (25' x 40')
NORTH WALL HEPA FILTER BANK	836m^2 (9,000 ft^2) @ 25,488m^3/min (90,000 ft^3/min) - horiz. flow
BONDED STORAGE	two identical areas, one atop the other
CRANES: 2 ea of 31,752Kg (35 ton)	hook heights of 21.0m (69') and 24.4m (80')
OTHER SERVICES: central vacuum cleaning system, compressed air and compressed nitrogen, intercoms, and telephones	**LOCATIONS**: Columns: C-2, C-8, D.7-8, E-2, F-4, F-6 (located as required)



BUILDING 29 FIRST FLOOR PLAN

SSDIF HIGH BAY CLEANROOM

SSDIF PRECISION CLEANING ROOM

DESCRIPTION: The Precision Cleaning Room is a $56m^2$ ($592\ ft^2$), Class 1,000 (M4.5), horizontal, unidirectional flow cleanroom. It was designed to supply precision cleaning services for spacecraft hardware and ground support equipment. This area contains the necessary services, equipment, and supplies, including a Quadrex Shear Stress Precision Cleaning System.

MODE OF OPERATION: The facility is staffed with trained precision cleaning personnel providing a variety of cleaning services. Complete, detailed procedures govern all applications, and QA personnel provide inspection capability for all cleaned parts. Access to the facility is restricted, and operations are supported by a $46m^2$ ($500\ ft^2$) Pre-Cleaning Room.

SIZE	8.5m L x 6.4m W x 3.1m H (28' x 21' x 10')
CLEANLINESS: CLASS 1,000 (M4.5)	periodic monitoring
AIR VELOCITY	31m/min (100'/min), minimum
TEMPERATURE	18.3 to 23.9 °C (65 to 75 °F)
RELATIVE HUMIDITY	40 to 50%
ENTRANCE (HARDWARE)	two 1.83m (6') double doors, one with airlock; also a pass-through
HEPA FILTER WALL	$26m^2$ ($280\ ft^2$) @ $793m^3$/min ($28{,}000\ ft^3$/min) - horiz. flow
OTHER SERVICES: central vacuum cleaning system, shear stress precision cleaning system, compressed nitrogen, video monitoring system, communication system	**LOCATIONS**: See facility layout drawing for details.

3.8 BUILDING SERVICES
3.8.1 ELECTRICAL POWER
3.8.1.1 NORMAL HOUSE POWER

Normal house power in the Bldg. 7, 10, 15, 29 complex consists of the following circuits:

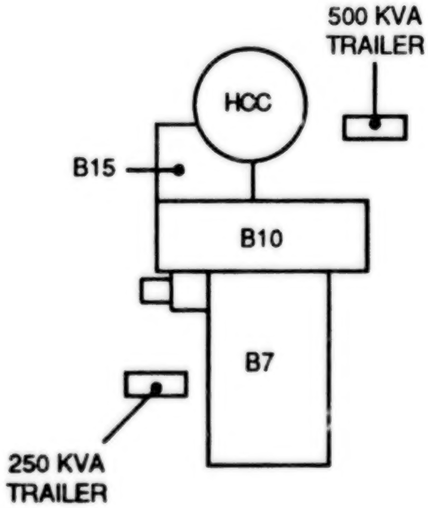
Voltage (AC)	Hz	Phase	Current (Amp)
120/208	60	1	up to 30 per outlet
277/480	60	3	up to 100 per outlet

All circuits can be backed up by emergency power. It should be noted that all transformers are Y connected with the center tap grounded. There is no special regulated power for computers. Instrument grounding plates are also available throughout the complex.

3.8.1.2 EMERGENCY POWER SYSTEMS

DESCRIPTION: The emergency power systems for the test facilities in Buildings 7 and 10 consist of a 250-KVA diesel generator and a 500-KVA diesel generator, respectively. The generators and their associated switchgear cabinets are permanently installed at each location. A portable 400-KVA diesel generator is available on an as- and where-needed basis.

MODE OF OPERATION: Each generator will start and transfer automatically to the building supply when commercial power has been lost longer than 15 seconds (time delay is adjustable). Due to the limited capacity of these units, normal procedure after a power failure is to initiate an orderly restart of selected facilities up to the capacity of the emergency system. For a power outage, test conditions are maintained for at least one hour by the emergency generator; and then, transfer back to commercial power is effected as promptly as possible. The portable generator must be connected, started, and transferred manually.



EMERGENCY GEN. LOCATIONS

BLDG. 10 EMERGENCY GEN.

3.8.2 HIGH PRESSURE GN_2 GENERATING AND STORAGE SYSTEMS (FACILITIES 258 AND 263)

DESCRIPTION: There are separate high pressure GN_2 generating and storage systems for Buildings 7 and 10. The Building 7 system is comprised of a liquid pressurization pump, an ambient air heat exchanger, and a manifolded rack of forged steel gas storage bottles. The Building 10 system has a dual pump arrangement with a single ambient air heat exchanger. The Buildings 7 and 10 GN_2 storage systems are connected, and both are filled by the Building 10 GN_2 system, with the Building 7 GN_2 system serving as a hot backup.

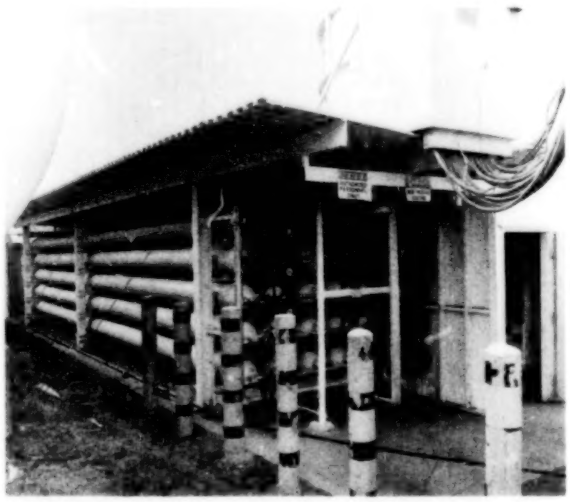
MODE OF OPERATION: The high pressure pump increases the liquid pressure to 13.8Mpa (2,000 psig). The liquid is evaporated in the heat exchanger and transferred to the storage bottles which are maintained at 14.1Mpa (2,045 psig) maximum. The gas is withdrawn for use in each building after a two-stage pressure reduction to 2.4Mpa (350 psig) and 0.69Mpa (100 psig), respectively.

PARAMETERS	
GN_2 generation:	227 standard m^3/hr (8,000 ft^3/hr) each pump
Storage capacities:	Bldg. 7 - 558 standard m^3 (19,700 ft^3) Bldg 10 - 2,322 standard m^3 (82,000 ft^3)

PHYSICAL CHARACTERISTICS

	Building 7	Building 10
Pressurizing engine pump:	1	2
LN_2 storage dewar - 1,893 lit (500 gal):	1	1
Vaporizing heat exchanger:	1	1
Storage bottles:	6	25


BLDG 10 VAPORIZER

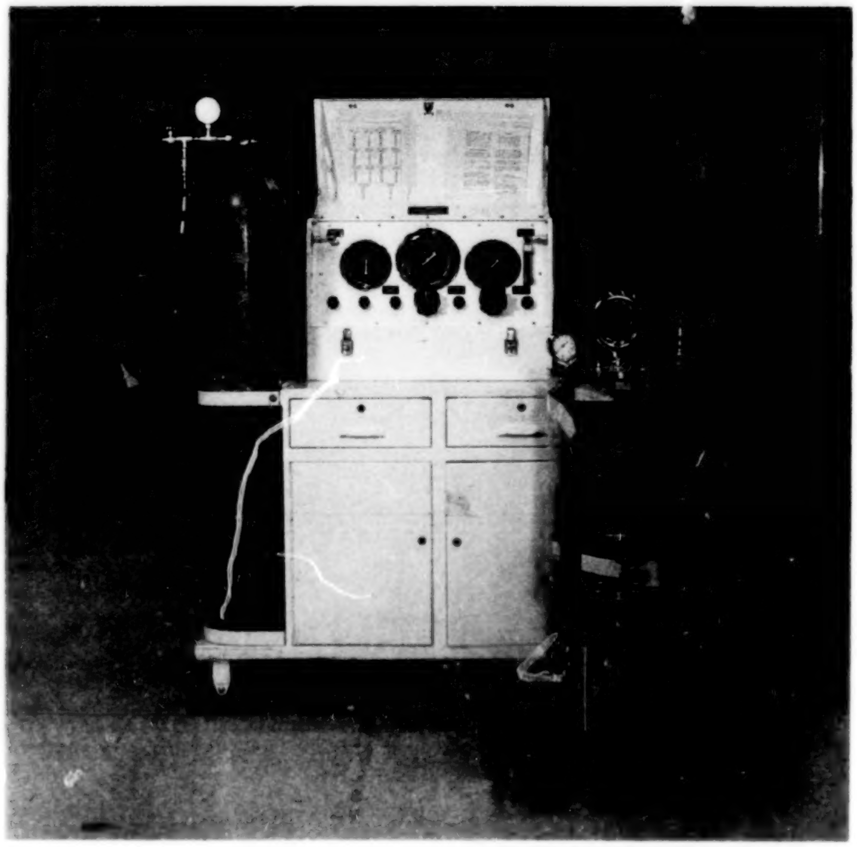

BLDG 10 GN_2 STORAGE BOTTLES

3.8.3 CRANE CAPACITIES

*TYPE (Except as otherwise noted, the cranes are bridge cranes.)
a - Variable hoist control; b - Trolley crane (no bridge); c - Hoist only (no trolley or bridge); d- Dual trolley; e - Wooden traversing

Bldg/Crane No.	Location	*Type	Capacity Kg/(Ton)	Hook Height m/(ft & in)
5-2	Rm W51, Integration	c	2,722/(3)	6.3/(20'8")
5-4	High Bay Lab		1,814/(2)	14.7/(48'2")
5-5	High Bay Lab	d	18,144/(20) 2,722/(3)	7.1/(23'2") 8.0/(26'4")
5-6	Weld Shop		1,814/(2)	3.5/(11'6")
5-13	Rm W51, Integration	b	2,722/(3)	6.1/(20')
5-19	Truck Lock (west)	b	1,814/(2)	3.8/(12'6")
5-20	Truck Lock (east)		13,608/(15)	7.0/(23')
7-4	Rm 040, Vib Lab		6,804/(7.5)	13.4/(44') To Basement
				7.2/(23'6") To B10 Floor
7-6	Rm 036, Vib Lab		6,804/(7.5)	13.2/(43'3") To Basement
				7.2/(23'6") To B10 Floor
7-7	Rm 034, Vib Machine Shop	b	227/(0.25)	4.6/(14'11")
7-8	Rm 032, Mass Properties	b	1,814/(2)	4.5/(14'9")
7-9	Rm 026, Vib Lab	b	1,814/(2)	4.4/(14'6")
7-10	Rm 026, Vib Lab	b	1,814/(2)	4.7/(15'5")
7-13	Truck Lock		9,072/(10)	10.6/(34'8")
7-14	Rm 190A, Integration	b	1,814/(2)	4.3/(14'1")
7-15	Rm 190A, Integration	b	1,814/(2)	4.2/(13'11")
7-16	High Bay Lab		4,536/(5)	8.6/(28'4")
7-17	High Bay Lab		4,536/(5)	8.6/(28'4")
7-18	SCA Clean Room	a	4,536/(5)	8.4/(27'5")
7-19	CIA Clean Room	a	6,804/(7.5)	13.2/(43'5") To Basement
				8.7/(28'8") To 1st Floor
7-20	SCA Clean Room (RFI)	a	907/(1)	4.7/(15'4")
7-30	Acoustic Chamber		6,804/(7.5)	8.8/(28'10")
10-1	High Bay Lab	a	13,608/(15)	20.3/(66'6")
15-2	High Bay Lab	a	6,804/(7.5)	11.9/(39'1")
15-3	HCC Rotunda	b	2,722/(3)	7.7/(25'3")
15-4	HCC Rotunda	b	2,722/(3)	7.8/(25'6")

Bldg/Crane No.	Location	*Type	Capacity Kg/(Ton)	Hook Height m/(ft & in)
15-5	Modal Survey Facility	a	907/(1)	6.7/(22')
15-6	Modal Survey Facility	a	454/(0.5)	5.8/(19')
15-7	Modal Survey Facility	d	454/(0.5)	4.9/(16')
29-1	High Bay, Clean Rm #2	a	31,752/(35)	21.0/(69')
29-2	High Bay, Clean Rm #1	a	31,752/(35)	24.4/(80')
29-3	Rm 135, Ship/Receive	a	31,752/(35)	20.3/(66'9")
29-4	Rm 136, Flt Hdwe Staging	a	31,752/(35)	20.2/(66'4")
29-5	Rm 150	a	4,536/(5)	7.6/(25')
303 30-8, Small Coil	Central Coil Bldg	e	907/(1)	7.6/(25')
305 30-1, Large Coil	Inner Truck Lock	b	2,722/(3)	4.2/(13'10")
305 30-2, Large Coil	South Side of Bldg	c	2,268/(2.5)	6.7/(22')
305 30-3, Large Coil	Coil Centerline	c	2,268/(2.5)	5.8/(19')
305 30-4, Large Coil	Outer Truck Lock	b	4,536/(5)	5.8/(19')



HYDRASET & CONTROL CONSOLE

3.8.4 HYDRASETS

Hydrasets are hydraulic, remotely-controlled lifting devices which are placed between the crane hook and the load. They can position a load vertically in increments of 0.025mm (0.001"). Each is proof-tested at 200% of the rated load, and tested at 125% of payload, before lifting flight hardware. All are exercised monthly; this is in addition to other routine testing and maintenance.

POSITIVE FLUID RETENTION SYSTEM, CONSOLE-OPERATED HYDRASETS					
Qty.	Capacity Kg/(Ton)	Usable Range Kg/(Lb)	Stroke cm/(in)	Rigging Length Eye-to-Eye	
				Min cm/(in)	Max cm/(in)
1	454/(0.5)	91-363/(200-800)	30.5/(12.00)	59.1/(23.25)	89.5/(35.25)
1	907/(1.0)	181-726/(400-1600)	15.2/(6.00)	65.4/(25.75)	80.0/(31.50)
3	907/(1.0)	181-726/(400-1600)	31.3/(12.32)	80.8/(31.81)	112.1/(44.13)
1	2268/(2.5)	454-1814/(1000-4000)	14.6/(5.75)	65.4/(25.75)	80.0/(31.50)
3	2268/(2.5)	454-1814/(1000-4000)	30.5/(12.00)	82.9/(32.63)	113.4/(44.63)
4	4536/(5)	907-3629/(2000-8000)	30.5/(12.00)	83.2/(32.75)	113.7/(44.75)
2	9072/(10)	1814-7258/(4000-16,000)	15.2/(6.00)	79.7/(31.38)	94.9/(37.38)
3	9072/(10)	1814-7258/(4000-16,000)	30.5/(12.00)	95.6/(37.63)	126.1/(49.63)
1	18,144/(20)	3629-14,515/ (8000-32,000)	30.5/(12.00)	109.2/(43.00)	139.7/(55.00)
MANUAL-TYPE HYDRASETS					
1	454/(0.5)	91-363/(200-800)	30.5/(12.00)	56.5/(22.25)	87.0/(34.25)
1	907/(1.0)	181-726/(400-1600)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)
1	2268/(2.5)	454-1814/(1000-4000)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)
1	4536/(5)	907-3629/(2000-8000)	15.2/(6.00)	65.4/(25.75)	80.6/(31.75)
1	4536/(5)	907-3629/(2000-8000)	30.5/(12.00)	65.4/(25.75)	95.9/(37.75)

3.8.5 LIFTING AND HANDLING DEVICES

A wide variety of devices is available for lifting and transporting hardware and personnel. These devices can be used to move up to 7,031Kg (15,500 pounds), or access areas up to 13.7m (45') high.

Type	Capacity Kg/(Lb)	Platform Size m/(ft)	Lift Height m/(ft)
Fork Lifts			
Clark	7,031/(15,500)	1.22 x 1.83/(4 x 6)	3.05/(10)
Clark	4,536/(10,000)	1.22 x 1.22/(4 x 4)	7.62/(25)
Yale	4,536/(10,000)	1.22 x 1.22/(4 x 4)	3.05(10)
Schreck	1,814/(4,000)	0.91 x 0.79/(3 x 2.6)	4.72/(15.5)
Moto-Truc	1,361/(3,000)	0.91 x 0.79/(3 x 2.6)	3.35/(11)
EZ Lift (3 each)	680/(1,500)	0.69 x 0.63/(2.3 x 2.1)	1.65/(5.4)
Flat Bed Electric Truck	1,814/(4,000)	2.44 x 0.91/(8 x 3)	0.10/(0.33)
Tow Tractors			
Clark	2,268/(5,000)	N/A	N/A
PettiBone	1,361/(3,000)	N/A	N/A
Raymond (2 each)	91/(200)	N/A	N/A
Lift Tables			
Economy Lift Table (2 each)	454/(1,000)	0.91 x 0.61/(3 x 2)	0.31/(1)
Raymond Pallet Jack	454/(1,000)	1.22 x 0.69/(4 x 2.3)	0.15/(0.5)
Rol-Lift Pallet Jack (2 each)	2,495/(5,500)	1.22 x 0.69/(4 x 2.3)	0.15/(0.5)
Personnel Lifts			
Upright	907/(2,000)	3.66 x 2.13/(12 x 7)	10.97/(36)
Upright	340/(750)	1.68 x 0.91/(5.5 x 3)	5.49/(18)
Upright Air-Deck	227/(500)	2.44 x 0.91/(8 x 3)	7.52/(24.7)
JLG	227/(500)	0.91 x 0.61/(3 x 2)	13.72/(45)
Balleymore	159/(350)	0.66 x 0.66/(2.2 x 2.2)	10.97/(36)
Upright	136/(300)	0.61 x 0.61/(2 x 2)	5.79/(19)

3.8.6 DOORWAY AND OTHER CLEARANCES FOR BUILDINGS 7, 10, AND 29

These dimensions are presented to assist the test program coordinator in pretest planning efforts. Note that building modifications and the addition of new building appurtenances may cause these dimensions to change, or to obstruct the free movement of test items. For items which approach clearance sizes, or for bulky, shuttle-size experiments, payload handling procedures should be prepared based on a site visit.

Description	Location	Dimensions meter/(ft & in)
Roll Up Door	B7 SCA - North	5.94 W x 5.97 H (19'6" x 19'7")
"	B7 SCA - South	5.94 W x 5.97 H (19'6" x 19'7")
"	B7 to B10	5.84 W x 5.87 H (19'2" x 19'3")
"	B10 to B15	5.94 W x 6.07 H (19'6" x 19'11")
"	B15 to Outside	7.29 W x 6.27 H (23'11" x 20'7")
"	B7 Truck Lock to Outside	4.62 W x 4.50 H (15'2" x 14'9")
"	B7 Truck Lock to B10	4.88 W x 3.94 H (16' x 12'11")
"	B7 Truck Lock to Rm 190 (Integ. Area)	3.63 W x 4.19 H (11'11" x 13'9")
"	B7 Corridor to Rm 190 (Integ. Area)	3.38 W x 4.19 H (11'1" x 13'9")
"	SCA to CIA	3.67 W x 3.35 H (12'1/2" x 11')
"	B29 Rm 130 Clean Rm to Rm 140 Ship/Rec	7.62 W x 12.19 H (25' x 40')
"	B29 Rm 140 Flt Hdwe Staging Area to B10	7.62 W x 12.19 H (25' x 40')
"	B29 Rm 160 Flt Hdwe Staging to Outside	5.03 W x 5.49 H (16'6" x 18')
"	B29 Rm 160 Flt Hdwe Staging to Rm 140 Ship/Rec	6.10 W x 5.94 H (20' x 19'6")
"	B29 Rm 150 High Bay to Rm 140 Ship/Rec	7.62 W x 7.62 H (25' x 25')
"	B29 Rm 140 Shipping/Receiving to Outside	7.62 W x 7.62 H (25' x 25')
Walkway	Bridge over B7 - B10 Corridor	5.49 W x 5.44 H (18' x 17'10")

Description	Location	Dimensions meter/(ft & in)
A/C Duct	Duct over B7 - B10 Corridor	5.49 W x 5.84 H (18' x 19'2")
Hinged Doors (2 each)	Large RFI to SCA	5.64 W x 5.46 H (18'6" x 17'11")
"	B7 Rm 036 & B7 Rm 040 (C220 Vib Cells) to B10	4.93 W x 8.97 H (16'2" x 29'5")
"	B7 Sub-Basement to B335 Vib Cell	2.44 W x 5.08 H (8' x 16'8")
"	Acoustic Facility to B10	4.55 W x 10.31 H (14'11" x 33'10")
"	HCC Rotunda to B15	7.31 W x 7.16 H (24' x 23'6")
"	Small RFI	2.13 W x 2.21 H (7' x 7'3")
Elevator	B7 Freight Elevator	3.05 W x 2.92 L x 2.29 H (10' x 9'7" x 7'6")
"	B7 Basement to Sub-Basement Lift	1.78 W x 2.57 L x 2.64 H (5'10" x 8'5" x 8'8")
"	B7 Personnel Elevator	1.17 W x 1.93 L x 2.13 H (3'10" x 6'4" x 7')
Floor Opening	B10 Near B7 Truck Lock	2.74 W x 3.05 L (9' x 10')
"	B10 Near SES Chamber	3.05 W x 6.10 L (10' x 20')
"	B7 Near Freight Elevator	3.91 W x 5.13 L (12'10" x 16'10")

3.8.7 AIR BEARING SUPPLY STATIONS

The house air system delivers compressed air at 621Kpa (90psig) to the following locations:

Building 7, 1st Floor Locations		Building 10, 1st Floor Locations	
SCA cleanroom, north wall 0.9m (3') east of column D7 RB Column D10 RB Column D13		Column 16 EX 4.6m (15') west of column 23 EX Column 16 J	
Max. vol. (std. m^3/min)	$2.83m^3$ ($100ft^3$)	Max. vol. (std. m^3/min)	$2.83m^3$ ($100ft^3$)
Connections	Hansen - 2.54cm (1") quick disconnect	Connections	Hansen - 2.54cm (1") quick disconnect

3.8.8 AIR BEARINGS

DESCRIPTION: Air bearings and matching jacks provide both mobility and vertical height adjustment of the load. By bolting the air bearings to an object and applying air pressure, the object rides on a cushion of air and is easily moved and maneuvered. The jacks, which are attached to the air bearings, are needed to raise the load off the floor before air pressure is applied.

Quantity	Size	Capacity
4	41cm (16") diameter	907Kg (2,000 lb)
4	56cm (22") diameter	1,814Kg (4,000 lb)
4	71cm (28") diameter	2,722Kg (6,000 lb)
4	86cm (34") diameter	4,536Kg (10,000 lb)

AIR BEARING

3.8.9 GN_2 PURGE OUTLETS

DESCRIPTION: Gaseous nitrogen is available for purge at several locations in the cleanrooms. A GN_2 supply can be installed for special applications at any location in the Building 7/10/15/29 complex when defined by the experimenter in advance.

Location	Supply Line	Maximum Delivery Pressure	Connection
SCA cleanroom (4 locations)	0.95cm (3/8") nominal	621Kpa (90psig)	.64cm (1/4") *QC
CIA cleanroom (2 locations)	0.95cm (3/8") nominal	621Kpa (90psig)	.64cm (1/4") *QC

* 1/4" Quick Connect coupling (MIL Spec M - 4109-04)

3.8.10 LN_2 FILL STATIONS

DESCRIPTION: LN_2 stations for dewar filling are provided in the locations shown:

Location Column #/Floor/Bldg.	Supply Line	Maximum Delivery Pressure	Connection
G-6/Basement/7	1.3cm (1/2") nominal	172Kpa (25psig)	** 1.3cm (1/2") AN
East wall - Facility 255 LN_2 storage shed	1.3cm (1/2") nominal	172Kpa (25psig)	** 1.3cm (1/2") AN
Interior - Facility 255 LN_2 storage shed	1.3cm (1/2") nominal	172Kpa (25psig)	** 1.3cm (1/2") AN

** 1/2" AN (American National) fitting

3.8.11 LN_2 STORAGE VESSELS

Large quantities of liquid nitrogen are maintained to provide cryogenic cooling of the diffusion pump cold traps and shrouds of the thermal vacuum chambers in Buildings 7 and 10, and as a supply for the high pressure gas generators. Also, small portable vessels can be filled at the Building 7 facility.

3.8.11.1 BUILDING 7, 106K LITER (28K GAL) DEWAR (FACILITY 255)

DESCRIPTION: This double-walled, vacuum-jacketed storage vessel is comprised of two concentric, horizontal, steel cylinders. The outer shell is 18.3m (60') long by 3.7m (12') in diameter. The inner tank has a capacity of 106K liters (28,000 gallons) of LN_2 with a 5,299 liter (1,400 gallon) ullage volume. An ambient temperature vaporization coil maintains a tank pressure of 138Kpa (20psig). Valves are provided to control the filling and withdrawal of the cryogenic fluid.

MODE OF OPERATION: Insulated plumbing conducts the cryogenic fluid to a distribution manifold in Building 7, where it is transferred as required to each chamber and withdrawal station through insulated or vacuum-jacketed lines.

3.8.11.2 BUILDING 10, 242K LITER (64K GAL) DEWAR (FACILITY 257)

DESCRIPTION: This double-walled, vacuum-jacketed LN_2 dewar is comprised of two concentric spheres supported by tubular columns. The 7.9m (26') diameter inner vessel is constructed of welded aluminum plates and the 8.5m (28') diameter outer casing is constructed of welded steel plate. The inner tank has a capacity of 242K liters (64,000 gallons) with a 22.7K liter (6,000 gallon) ullage volume. An ambient temperature vaporization coil provides a tank pressure of 138Kpa (20psig). Valves are provided to control the supply and withdrawal of LN_2.

MODE OF OPERATION: Insulated plumbing conducts the cryogenic fluid to a distribution panel in the basement of Building 10, where it is directed as required to the diffusion pump elbow cold walls and the shroud LN_2 recirculating system.

ENGINEERING SERVICES DIVISION

INTEGRATION AND TEST USER'S GUIDE

ENGINEERING SERVICES DIVISION USER'S GUIDE OUTLINE

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II. ESD USER'S GUIDE: INTEGRATION AND TEST

1.0 Introduction

The following pages present an overview of the integration and testing services provided by the Engineering Services Division (ESD), Code 750. Included is a brief description of the organization along with the point of contact for those wishing to have integration and testing work done. Following this is an overview of our facilities and capabilities. We have also included a list of documents required to obtain integration and testing services as well as special considerations and suggestions in order to make things easier for our customers and ensure the best service possible.

2.0 Organizational Responsibilities

The ESD, Code 750, is responsible for the overall management of the Goddard Space Flight Center (GSFC) environmental testing facilities located in Buildings 7, 10, 15, 29, and at the Magnetic Test Facility. The operation and maintenance of the facilities within the ESD has been delegated to the Environmental Test Engineering & Integration Branch, Code 754. Supporting the ESD in the administration of the testing workload, identifying the funding and personnel resource requirements, and developing the test verification plans is the Verification Engineering Office, Code 750.2.

2.1 Organizational Contacts

In order to assist in the planning for, and expediting of, the item to be tested through the facility complex, Figure 3 identifies the principal contacts. These contacts can provide assistance in determining needed resources (funding, personnel and test fixtures) to accomplish the test program. The organizational group listed should be the point of contact in scheduling any tests and relaying test requirements.

2.2 Verification Engineering Office

The Verification Engineering Office (VEO) provides mid-level and senior-level engineers who develop a plan to verify that your test item has been tested to the GSFC specification tailored to your flight project. The VEO verification managers are involved throughout the project life, and develop the verification plan, generate cost estimates and work directives, and assist in coordinating the test facility scheduling. The VEO managers support in-house and out-of-house GSFC projects by serving on Source Evaluation Boards/Tech Panels, developing/reviewing statements of work for request for proposals (RFP), and reviewing test plans and procedures. Initial contacts for both GSFC supported programs and reimbursable projects (work from other centers, DOD, etc.) should be established with this office.

Figure 3. Code 750 Contacts For Testing and Integration

Verification Engineering Office (Code 750.2)

Verification Managers
Code 750.2

Group Leader (Spacecraft)
Bldg. 7-Rm. 135A
(301) 286-6442

Group Leader (Instruments)
Bldg. 7-Rm. 129
(301) 286-4347

Environmental Test Engineering & Integration Branch (Code 754)

Structural/Dynamic Testing
Section Head (Code 754.1)
Bldg. 7-Rm. 165
(301) 286-6480

Electromagnetic Testing
Section Head (Code 754.2)
Bldg. 7-Rm. 157
(301) 286-6201

Mechanical Integration
Section Head (Code 754.3)
Bldg. 7-Rm. 159
(301) 286-5193

Space Simulation Testing
Section Head (Code 754.4)
Bldg. 7-Rm. 163
(301) 286-6058

2.3 Environmental Test Engineering & Integration Branch

The Environmental Test Engineering & Integration Branch is responsible for providing the test personnel and facilities to accomplish the test program. The test facilities include thermal vacuum chambers, vibration shakers, static and dynamic loading cells, and electromagnetic interference generators. The Branch is assisted by a support contractor who operates and maintains the facilities. The Branch also generates the detailed manpower estimates to perform the required test, and assesses the availability of the facilities. Any requirements for new or modified facilities or expanded test capabilities should be addressed through this office. While undergoing the various tests in thermal vacuum, vibro-acoustics or EMC, a test engineer for each area will be assigned to assist in test set up, instrumentation, and data analysis. The test engineer interacts with the project early in the design and fabrication phase to assist with test issues. It is required that the project provide a test plan well in advance of any tests in order that special requirements may be met and a test procedure can be prepared by the Branch.

3.0 Facilities Overview

The Environmental Test Engineering & Integration Branch maintains a full spectrum of facilities needed for complete spacecraft (S/C) and instrument mechanical integration and environmental testing. When coupled with project and Code 754 expertise, the facilities provide the outstanding, comprehensive capabilities required to execute a complete S/C integration and test (I&T) program. All major facilities except the Magnetic Test Facility are contained within the same building complex (Buildings 7, 10, 15, and 29). The Magnetic Test Facility is located off the main campus to provide magnetic isolation and control. In summary, facilities are provided for thermal vacuum, thermal balance, thermal vacuum bakeout, electromagnetic interference, magnetic, static load, vibration, centrifuge, separation, shock, modal and deployment testing, and for mass properties measurements, data analysis, and data collection. Other facilities important to the I&T process contained within the complex are clean rooms (including the largest in the world), clean benches, cleaning facilities, optical alignment and measurements, and spin balancing, along with areas for cable fabrication and thermal blanket fabrication.

4.0 Capabilities

4.1 Overview

The knowledge, skills, and experience of the personnel working in the organization provide the essential technical link allowing the facilities to be used to conduct tests. Branch engineers are assigned to work with specific projects early in the planning phase; and continuously through the project execution cycle to facilitate advanced preparation and design of the test series. Project engineers are encouraged to use this expertise early in project planning phases to best use their contributions. Also, the personnel are capable of providing design consultation to project engineers in specific disciplines related to the major areas of environmental testing: thermal/vacuum, structural, and electromagnetic.

Capabilities are available to accept hardware design tasks to provide turn-key design and fabrication services for flight programs. From ground support equipment (GSE) through flight subsystems, Code 754 provides quality, experienced people to execute these specialized tasks.

4.2 Procedure Writing

Prior to any test being executed by Code 754, a test procedure must be written. The procedure takes information made available in the test plan (written by the project) and adds facility procedure information. Code 754 personnel write these procedures using the test plan and direct interaction with the project engineers for information. Generally speaking, the nature and complexity of the procedures will vary significantly from one test to another and from one test item to another.

4.3 Off-Site I&T Support

The GSFC often manages S/C and instrument development programs which are executed at contractor sites. During the I&T phase of these programs, it is often advantageous for program managers to draw upon experienced personnel to consult in these specialized areas. Code 754 has available both civil servants and contractor personnel who are experienced in test support planning and conducting S/C environmental test programs. Managers are encouraged to draw on these resources during this program phase. Support in terms of test plan and procedure review, contractor site inspection and review, test oversight, and post test data analysis is available.

4.4 Analysis

Expertise and tools are available to perform detailed design analyses to support both test design and flight hardware design. In terms of testing, many of these analyses are required for proper design of the test, and of test support systems including fixturing and custom facility modification. Experienced analysts are available to support and perform thermal, structural, electromagnetic, safety, modal, coupled loads, system's safety, stress, finite element, and other types of analysis. Project engineers are encouraged to use this base of expertise, a base which is specifically tailored to analysis needed for test design.

4.5 Proofing

Most activity related to lifting, moving, supporting, rotating, or otherwise handling hardware, flight or otherwise, requires support hardware that has been proof tested and analyzed for strength and stability. The Environmental Test Engineering & Integration Branch maintains the capability in-house to perform all testing and analysis required to satisfy NASA and Goddard requirements for lifting and support equipment certification.

4.6 Integration

Personnel experienced in and fully capable of executing the full spectrum of work needed for S/C mechanical integration are available within Code 750. The difficult task of integrating separate subsystems and structures into a functioning mechanical system represents one of the most

challenging tasks faced by the S/C I&T managers. These Code 750 personnel provide the experience, tools, and facilities to properly integrate the S/C and ensure correct alignment and operation.

4.7 Design

The organization maintains the capability of designing all types of flight related hardware. Experienced design and analysis personnel, coupled with modern facilities, provide the ability to address a multitude of hardware design problems. These include flight hardware from small sub-elements through major subsystems; mechanical ground support equipment including handling gear, turnover dollies, etc.; and environmental test facility related hardware including facility modifications and complex fixturing. A diverse group of analysis personnel provide support to the design program to assure success and provide the documentation needed to certify flight systems.

A related area of capability is in flight and GSE wire harness system design and fabrication. Full S/C harness fabrication jobs have been successfully executed by Code 754's experienced group of wiring personnel. Both ground support and flight cabling work can be executed by this group.

4.8 Blankets

Thermal blanket design, fabrication, and application capabilities are provided by Code 750. Experienced personnel, together with blanket fabrication facilities, provide the capability for complete S/C blanketing.

5.0 Documentation Requirements

In order to insure that testing in Code 750 facilities proceeds as smoothly as possible, project technical managers or the responsible ESD test personnel must prepare certain documentation. These documents must be provided in a timely manner to ensure that required test preparations are completed prior to the test date. The approved verification plan will be used as the basis for the test program. The test levels appear in the verification specification prepared by Code 750.2.

5.1 Test Plans

The cognizant project technical manager or component/subsystem/system lead engineer is responsible for preparing the individual test plans. Each plan is normally required 30 days before testing for components and subsystems, and as much as six months before complicated tests such as High Capacity Centrifuge loads testing or system level thermal balance/thermal vacuum testing. At a minimum, each test plan must be approved by the project manager (or representative), the test item lead engineer, the verification manager, and the quality assurance representative. Each test plan will provide the information necessary to develop the facility test procedure and identify special fixturing and/or safety constraints required. A sample outline of the test plan contents is listed in Figure 4. More detailed information is available from the Verification Engineering Office, Code 750.2.

5.2 Test Procedures

Code 754 test personnel develop facility test procedures using project developed test plans. A unique test procedure is written for each test, even if the test is a repeat of a previously run test. The test procedure normally contains the item configuration, mounting details, instrumentation types and locations, handling/safety considerations, and data acquisition/reduction requirements. The project manager or lead engineer, verification manager, Code 754 test engineer, facility engineer, and quality assurance representative (as required by project) all sign approval of the test procedure.

5.3 Work Directives

A work directive (WD) provides the authorization for the test facility support contractor to initiate work to prepare for and conduct the test. A blank WD form is included as Figure 5. The Verification Engineering Office (VEO) verification manager assigned to the project prepares the WDs. Separate WDs are to be prepared for each test and are also to be prepared for a level of activity such as integration or clean room support. To avoid delays in performing the required tests, the initial contact for all test requests should originate with the VEO. The WD is generated from project requirements as stated in the test plan. From these requirements, the manpower and materials are estimated to complete the test. After project approval, the WD is processed and the test is initiated. The project is charged for the work performed on a monthly basis until completed. Additional work not identified in the original WD must be authorized by the verification manager, and approved by the project prior to being conducted. The verification manager maintains a weekly status of test charges which are available upon request.

5.4 Supporting Analyses

Lifting - All critical flight hardware test items requiring a crane for lifting must be accompanied by an approved lifting analysis. In addition, any non-flight hardware and GSE requiring a crane may need an approved lifting analysis if there is any risk to Code 754 facilities or personnel. Project shall perform this analysis and the appropriate Code 754 personnel shall verify it. The analysis applicability and content is defined in the following GSFC documents: (1) Procedure for Approval of Project Related Lifting Equipment, dated November 1992; and (2) Analysis Procedure for Spreader Bar Lift Stability. These documents are available from the Code 754 Branch Office.

OHA/Safety - The project shall prepare an Operations Hazard Analysis (OHA) which identifies the safety hazards involved in testing, and what measures will be taken to minimize risk to personnel and hardware. The project shall perform the analysis for the test item. Also, the Code 754 test engineer shall perform an OHA for the facility and its effect on the test item. The degree of complexity of the OHA depends on the size, weight, and cost of the test item, and may consist of a visual analysis for simple components.

Handling - The project shall identify any special precautions needed during transport, installation, and removal of the test item. This shall include sensitivity to contamination and electrostatic discharge, and whether it contains radioactive or hazardous materials, high pressure

Figure 4. Suggested Test Plan Outline

1.0 Introduction
- 1.1 Purpose
- 1.2 Test Objectives
- 1.3 Pass/Fail Criteria
- 1.4 Test Item Description
- 1.5 Test Facility
- 1.6 Desired Test Date
- 1.7 Work Directive Number
- 1.8 Fiscal and Labor Job Order Numbers
- 1.9 Applicable Documents

2.0 Test Organization
- 2.1 Test Team

3.0 Special Precautions/Instructions
- 3.1 Safety
- 3.2 Precautions
- 3.3 Contamination
- 3.4 Emergencies

4.0 Test Requirements
- 4.1 Test Operations
- 4.2 Procedure Redlining

5.0 Data Acquisition/Reduction
- 5.1 Data Acquisition
- 5.2 Data Reduction

6.0 Support Equipment
- 6.1 Instrumentation
- 6.2 Support Equipment

7.0 Test Program
- 7.1 Test Phases/Sequence
- 7.2 Test Specification
- 7.3 Test Limits

8.0 Pre-Test Operations

9.0 Test Operations
- 9.1 Test Item
- 9.2 Test Fixturing
- 9.3 Test Setup

10.0 Post Test Operations

GODDARD SPACE FLIGHT CENTER
ENGINEERING SERVICES DIVISION
CODE 750

WORK DIRECTIVE (WD)

WD NUMBER | ISSUE DATE - -

PROJECT | FUND SOURCE | MOD. NO.

FISCAL JON | ESTIMATED COST | LABOR JON | R.C. | APP. | FY

ITEM DESCRIPTION

SCH. START - - | ACT. START - - | FAC. CODE: | SCHED. COMPL. - - | ACT. COMPL. - - | ITEMS

EST. TECH HRS | SC | EST ENGR HRS | MC | TESTS RT | WD REF. | REQUESTOR | FI | ORG CODE

AUTHORIZED PERSON | FI | ORG CODE | EST MATERIALS COST | EST TRAVEL COSTS

LEVEL OF ASSEMBLY	MODEL	WORK CATEGORY (Do Not Check More Than One Block)			
☐ 1. SPACE SYSTEM	☐ 1. ENGINEERING	☐ 1. VIBRATION	☐ 9. LEAK	☐ 17. INSTRUMENTATION	☐ 25. COATINGS
☐ 2. SPACE CRAFT	☐ 2. STRUCTURAL	☐ 2. SHOCK	☐ 10. TEMPERATURE	☐ 18. SAFETY	☐ 26/ RADIATION
☐ 3. SUBSYSTEM	☐ 3. THERMAL	☐ 3. ACCELERATION	☐ 11. HUMIDITY	☐ 19. FIELD SUPPORT	☐ 27. BLANKETS
☐ 4. MODULE	☐ 4. PROTOTYPE	☐ 4. STATIC LOAD/BEND	☐ 12. THERMAL-VACUUM	☐ 20. MAINTENANCE	☐ 28. CLEAN ROOM
☐ 5. EXPERIMENT	☐ 5. PROTOFLIGHT	☐ 5. SPIN/BALANCE	☐ 13. THERMAL-BALANCE	☐ 21. TRANSDUCER CALIB	☐ 29. INTEGRATION
☐ 6. INSTRUMENT	☐ 6. FLIGHT	☐ 6. MODAL SURVEY	☐ 14. MAGNETIC	☐ 22. ACOUSTIC	☐ 30. SLIP
☐ 7. COMPONENT	☐ 7. SPARE	☐ 7. WT-CG-MOI	☐ 15. RECERT	☐ 23. OPTICAL	☐ 31. FLT HDW DESIGN
☐ 8. OTHER	☐ 8. OTHER	☐ 8. TV-BAKEOUT	☐ 16. RFI	☐ 24. DEPLOYMENT	☐ 32. OTHER

DESIGNER/EXPER: (LAST NAME)	FI	(Area Code, Exch. Extn) – x	ORG.	
TEST ENGINEER:	FI	(Area Code, Exch, Extn.) – x	ORG.	
VERIFICATION MGR:	FI	(Area Code, Exch, Extn.) – x	ORG.	SIGNATURE/DATE
SECTION HEAD:	FI	(Area Code, Exch, Extn.) – x	ORG.	
PROJECT MGR:	FI	(Area Code, Exch, Extn.) – x	ORG.	SIGNATURE/DATE
FINANCIAL ANALYST:	FI	(Area Code, Exch, Extn.) – x	ORG.	

February, 1993

Figure 5. Work Directive Form (Front)

GODDARD SPACE FLIGHT CENTER
ENGINEERING SERVICES DIVISION
CODE 750

WORK DIRECTIVE (WD)

WD NUMBER

HAZARDS

TEST SPECIFICATION

TEST PLAN/OTHER

CLEANLINESS REQUIREMENTS

NOTES:

February, 1993

Figure 5. Work Directive Form (Back)

tanks, and/or explosive devices. These precautions shall be provided to the cognizant Code 754 personnel responsible for the test.

5.5 Test Reports

At the conclusion of each test, the Code 754 engineer will prepare a report which describes the as-tested configuration, test data, results, and conclusions. An initial report which includes preliminary test data will generally be available within one week. The final report will be available for distribution within 30 days after completion of a simple test, and up to 60 days after a complex test. One copy of the report will be supplied to the project lead technical engineer.

6.0 Funding Requirements

There must be funding available for all integration and test work before a WD can be issued by Code 750. Without the WD, work cannot begin. It is imperative that a valid funded fiscal job order number be in the GSFC Financial Management Division computer in order to generate the WD. This applies to all GSFC projects, reimbursable work, and suballotments.

6.1 Planning For Integration And Testing

Code 754 generates an estimate for the work prior to issuing a WD. This estimate is only as good as the requirements provided. It is of utmost importance that the customer provide as much detail as possible so an accurate cost estimate can be generated. Good planning is absolutely necessary in order to keep the cost from escalating.

6.2 Fiscal Job Order Number (FJON)

Each WD requires a funded FJON in the GSFC Financial Management Division's computer before it can be issued. This FJON is a 12-digit number with the last two digits being -69, designating it for integration and test work. The number can be established only when 506 funding exists.

6.3 Integration And Test Charge Backs

The labor, materials, and travel costs are charged back to the FJON on a monthly basis. This is documented in the Financial Management Division Report ITT101A, and available from your verification manager and the GSFC Project Resource Analyst. This report gives a detailed costing for each WD, and a summary costing for each FJON. Additional cost reports generated by the Code 750 support service contractor, on a weekly basis, are also available from the verification managers.

6.4 Integration And Test Rates

The rates charged for technician and engineering support are established at the beginning of each fiscal year and approved by the Director of Engineering. These rates are for the Code 750 support service labor only. There is no direct charge for facility usage or civil service labor for all GSFC, suballotments, and Government reimbursable work. Integration and test work estimates are

not fixed price estimates, and may change as requirements change. It is very important to provide all requirements when estimating I&T costs, and to maintain schedule in order to keep these costs from escalating.

7.0 Special Considerations

Customers of the Environmental Test Engineering & Integration Branch must be aware of a number of considerations. The following paragraphs attempt to highlight the most important issues. In all cases, it is highly recommended that engineers and managers contact Code 754 Branch personnel as early as possible before coming into the Branch for work. Prior planning is by far the most important activity needed for efficient and effective I&T tasks.

7.1 Material Selection

In general, selection of materials comprising GSE (and sometimes in-flight hardware) is most important in the thermal vacuum test area. Cables, electrical connectors, fixtures, fasteners, and other elements that comprise the "unit under test" play critical roles dictating the success of the test and the final test costs. Under all circumstances, materials which are strong outgassers under vacuum must be avoided. Failure to conform to these requirements can lengthen the test time, substantially increase its cost (due to chamber time and post test cleanup); and under extreme cases, contaminate the flight hardware. Please consult with Branch personnel well in advance of fabricating or specifying these kinds of items. For reference purposes, NASA Reference Publication 1124 offers outgassing data for a large number of commercial materials.

7.2 Lead Times

Lead times required to support testing can be significant. For example, a thermal balance test requiring a complex thermal fixture could take 6 months or longer to prepare. Strength tests of nearly any complexity on flight hardware will take at least 3 months to prepare, and could take 6 months to prepare in cases of complex actuator or High Capacity Centrifuge-based tests. In general, larger or more complicated test items require longer preparation lead times. Failure to properly budget this time, or failure to address these problems early will impact the program's cost and schedule. The best way to address these problems is to consult with Branch engineers well in advance of your test requirement dates.

7.3 Test Environment Accuracy

Users of the test facility should be aware of certain issues when planning, designing, and executing environmental testing. One issue is accuracy. Every produced environment has allowable accuracy and variance tolerances. Some of these tolerances can be quite large. For example, random vibration spectrum input generally has allowable tolerance bands of ± 3 dB. Effectively, the actual level at a given spectrum point is allowed to be half or double what is specified, a substantially large variance. Another issue is generation of unwanted environments coincident with the desired environment. For example, vibration shakers generate stray electromagnetic fields and cross-axis vibration. Each environmental test will have a different set of issues. The user must understand these

issues so proper test planning and protection of vulnerable hardware can be assured, while enabling improved interpretation of test results and test data. Direct contact with the facility engineers early in the planning process will help assure quality test products.

7.4 Schedules

The Branch works a normal 8-hour work day. An exception is the thermal vacuum test group which supports test chamber control on a 24-hour, 7-day per week basis. However, activities related to setting up a thermal vacuum test still must be accomplished during normal work hours. If requested, overtime and multi-shift work can be supported for a short, high priority task. The customer needs to be aware, however, that overtime work will cost the project increased hourly charges. Also, extended overtime requirements will be difficult to support due to constraints on total amounts of overtime allowable, and due to personnel constraints. Requests for overtime support must be made in advance of the requirement. Normally, two day's notice is sufficient for planning purposes.

7.5 Facility Access

Facilities used in the I&T process are generally not reserved in advance for a particular project item. Experience shows that hardware schedules are so changeable that test schedules made in advance are usually unreliable. With other projects vying for the same facility, it makes little sense to "hold" a facility when schedules slip. Instead, the Branch uses the first-come, first-served philosophy which has been shown to work well over the long term. On a case by case basis, other arrangements are possible; managers should be aware that costs usually increase when these requests are fulfilled.

The test and integration facilities and the related personnel are usually quite busy. It is not unusual to have scheduling conflicts between competing projects. Resolution of these conflicts is normally handled locally between facility engineers and managers, lead project engineers, and the assigned verification managers. Normally, there is a hierarchy of conditions which will dictate the resolution: Launch date, tests in progress, relative project flexibilities, budgets, and test complexity and detailed requirements normally play the most important roles. Under rare conditions, resolution of the conflict will be handled by higher level managers within Code 700 and the project.

7.6 Contamination

Projects must inform Branch engineers what requirements for prevention of molecular and particulate contamination have been approved for their hardware so that appropriate handling and storage precautions can be planned. Inappropriate specifications of contamination needs could result in increased costs and schedules or damaged hardware. If you specify requirements less stringent than what is needed, your payload risks contamination. On the other nand, if more stringent requirements are specified than actually required, I&T costs will increase unnecessarily and the schedule will be drawn out. It is strongly suggested that project engineers properly understand their contamination requirements and clearly communicate those requirements to Branch engineers. The Branch will generate the necessary implementation plans and budgets for specific projects when requested.

Another issue of contamination is related to facility contamination. Through the use of improper materials, project hardware could well contaminate the test facility (i.e., thermal vacuum chambers). Under circumstances of gross contamination, the project will pay to have the facility cleaned to minimum standards.

Minimum levels of cleanliness must be maintained for all hardware while in a clean room. This means that project hardware must be compatible with other hardware coexisting in the clean room even if specific project requirements don't dictate it. This may be a cost item for the project.

In all cases, early and continuous communication with Code 754 personnel will help to alleviate any problems associated with these issues.

7.7 Safety

Safety is always of paramount interest to Code 754. Protection of people, flight hardware, and facilities (in that priority) takes precedence over all other requirements. Consequently, Code 754 management must be convinced that all potentially hazardous activities are being properly executed, and proper protection is being implemented. Any time a potentially hazardous activity is planned, project personnel are strongly advised to talk with Branch personnel early so that a reliable safety assessment can be made. Without proper planning and precautions, the activity will not be supported.

In order to assess any safety issue, the Branch may require an in-house analysis of the condition. Project is responsible for providing funds to do this. Examples of issues of particular concern are: hazardous gasses and liquids (such as ammonia, chlorine, and caustics), radioactive materials, flammable materials, stored energy in the forms of spinning masses, pressurized systems, sprung systems, batteries, and chemicals (explosives). Unusual handling or lifting requirements are also of concern. Stability, controllability, and strength of the lifting system must be analyzed.

7.7.1. Safety Manual

The Engineering Services Division publishes a Safety Manual which discusses some of these issues in greater detail. Project engineers working in the facility complex are encouraged to obtain a copy and read and understand it.

7.7.2 Risk Assessments

When deemed appropriate by the Branch head or Branch engineer, Code 754 will perform a detailed risk assessment study prior to executing an activity in question. The assessment will define specific risks, estimate likelihood of the risk, and describe the likely result of the risk. As part of the study, the Branch will make recommendations on how to reduce the risk, or eliminate the adverse outcome of the risky event.

7.7.3 Safety Procedures

Under certain conditions, a safety procedure must be written to address the activity needed to alleviate a specific risk. Code 754, in conjunction with Code 205 and project personnel, will write the safety procedure. Codes 205 and 754, a project representative, and others if circumstances dictate, will approve the procedure.

7.8 Cost Drivers

There are certain issues which, if not properly handled, serve to increase customer costs. These cost drivers are described briefly below.

7.8.1. Early Involvement

In general, the best way to assure minimum cost is to bring Code 754 personnel, working with the verification manager, on board as early as possible. Having a Branch representative work with the project early provides several important benefits. Early understanding of project requirements will allow timely and efficient preparation for future activities. Last minute preparation tends to increase costs overall through overtime and less than optimal support systems design. Branch personnel can educate project personnel regarding issues and limitations important to the specific I&T process. Such education can help prevent unnecessary purchases, influence how a test or activity is designed, and assist in specifying the proper level of requirements.

7.8.2. Contamination Requirements

Strict contamination requirements will certainly increase costs. Special handling procedures, special materials, clean room use, repeated cleaning, and stringent vacuum chamber cleanliness requirements all serve to increase costs. Projects should ensure that the appropriate level of contamination avoidance is specified for their program.

7.8.3. Facility Modifications

Costs will increase any time modifications to a facility are needed to accomplish a specific activity. Here again, early involvement of Branch personnel is advantageous to assess facility limitations and develop possible plan-arounds, which might preclude the need for facility modifications.

7.8.4. Extensive Overtime

Late and slipped schedules are usually made up in the late I&T phase. Often, insufficient time is available to efficiently execute an activity. When this happens, the only recourse is to use overtime. Extensive overtime will quickly drive up costs. Projects are advised to allocate sufficient time for the I&T phase to allow the work to occur during normal hours. Early planning and Branch involvement can help alleviate this problem.

7.8.5. Bakeout Criteria

Flight hardware for payloads sensitive to molecular contamination require bakeouts. Bakeouts can be the largest expense item of an environmental test program. It is strongly recommended that project engineers carefully select the bakeout requirements. Overly stringent requirements are clear cost drivers. Proper planning of the bakeout sequence can also reduce costs. For example, if allowed by schedule and technical constraints, combining hardware for bakeouts will certainly reduce costs.

7.8.6. Instrumentation

In general, numerous channels of response instrumentation will drive up costs. Costs of providing, calibrating, applying, wiring, and removing the sensors, coupled with those of acquiring, analyzing, and reporting the data will increase costs. Projects should acquire all the data they need, but make sure they need all the data they acquire.

7.8.7. Functional Tests

Functional checks during and between tests are standard practice. However, when these checks are exceedingly long, or occur very frequently, or require partial or complete disassembly of the test setup, costs will be driven up. Project should ensure that the functional checks specified are the minimum reasonably useful.

7.9 Hardware Handling

The Branch in-house guidelines require that only Code 754 personnel shall operate the ESD cranes. Further, a certified hydraset operator must use an in-line hydraset for all lifts involving flight hardware. Advanced planning is required to avoid having people stand around while the appropriate equipment and operators are obtained.

7.10 Ground Support Equipment

Extensive ground support equipment will dictate involvement of Code 754 personnel in planning its placement. Project personnel should always be aware that, generally, they are not the only project using the facility. They may be required to take some specific action, or agree to certain limitations so that work for other projects can proceed.

7.11 Storm Codes

A system of weather codes has been established and is followed in the facility complex. The system is designed to warn project personnel and facility operators of specific hazardous weather conditions which might adversely affect facility operations. The system is set up to protect critical hardware and, to a lesser extent, personnel. The concern expressed by these codes is that sudden and unexpected power outages, power fluctuations, and power transients could occur. Such occurrences could generate undesirable conditions such as vibration transients, strand a payload on a crane hook, or cause a vacuum chamber to go down. Under the worst code, code three, in-house regulations

dictate that certain operations be stopped. The Code 754 Branch head and a project representative must sign a formal waiver before operations can proceed during code three conditions. Each kind of operation (lifting, vibration, load tests, etc.) will have different procedures and restrictions regarding the storm codes.

7.12 Proof tests

All lifting hardware and critical hardware fixtures must be proof tested prior to being used for flight hardware. Some of these requirements are specified in NASA Management Instructions (NMIs) and others in GSFC and Code 750 manuals, instructions, and policies. In addition to proof test requirements, the Branch requires that any critical lift be analyzed for lift stability. Project engineers or Code 754 can perform this analysis. See Figure 3 for additional information. Branch personnel are generally aware of these requirements and will help guide project personnel though the requirements maze.

8.0 Facility Upgrade Requirements

It is not unusual that some specific project test or integration requirement cannot be met by the current facilities. In general, because of some project-specific characteristic or requirement such as size, weight, special handling, test level requirement, accuracy, or data requirement, a modification to a facility or multiple facilities is required. In instances such as this, early planning and Branch personnel involvement is critical to successful and efficient execution of the activity.

9.0 Security And Building Access

Access to the Building 7/10/15/29 complex is controlled after normal working hours by locking all entrance doors. After hours access is obtained through the use of Key Cards issued by the Goddard Security Branch. Requests for Key Cards are made with a Key Card request form. The form is signed by the building complex Facilities Operations Manager (FOM) and by the Code 700 Security Coordinator. All personnel needing access to the complex for after hours test support must obtain a Key Card. For external personnel (GSFC Visitors), temporary Key Cards with given expiration dates will be issued. Please coordinate with the Verification Manager in advance of your work to ensure proper access.

10.0 Customer Feedback

Suggestions concerning the improvement in the quality of the support from the ESD during the test program is important. At the conclusion of each test activity, an evaluation sheet will be provided by the Code 754 test engineer for your comments. It is requested that these comment sheets be completed prior to your departure.

ABBREVIATIONS AND SYMBOLS

ABBREV SYMBOL	TRANSLATION
"	inch
' or '	feet
<	less than
>	greater than
%	percentage
μ	micro
Å	angstrom
A	ampere
AC	alternating current
A/C	air conditioning
Ag	silver
Al	aluminum
AMO	air mass zero
amp	ampere
AMU	atomic mass unit
AN	American National
ANSI	American National Standards Institute
APT	automatically programmed tool
atm	atmosphere
Au	gold
B or Bldg	building
^{o}C	degrees Celsius
CAM	computer-aided manufacturing
CAT	computer-aided test
CCTV	closed circuit television
C/F	cold finger
CFM	cubic feet per minute
CG	center of gravity
CIA	Calibration-Integration-Alignment
cm	centimeter
CNC	computer numerically controlled
COA	Cryogenic Optical Assembly
COBE	Cosmic Background Explorer
col	column
CRT	cathode ray tube
Cu	copper
D	depth
dB	decibel
DC	direct current
DEC	Digital Equipment Corporation
dia	diameter
dim	dimension
dm	decimeter
DOS	disk operating system
ea	each
EIP	experimenter's interface panel
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EP	Explorer Platform
ESD	Engineering Services Division
eV	electron volt
^{o}F	degrees Fahrenheit
FM	frequency modulation
fpm	feet per minute
FRF	frequency response function
ft	feet
g	gram
g	unit of acceleration (9.81 m/sec^2)
gal	gallon
GN_2	gaseous nitrogen
GRT	germanium resistance thermometer
GSFC	Goddard Space Flight Center
GVS	guard vacuum space
H	height
HCC	High Capacity Centrifuge
Hdwe	hardware
HEPA	high efficiency particulate air
HgXe	mercury xenon
Hp	horsepower
HP	Hewlett-Packard
Hr or hr	hour
HST	Hubble Space Telescope
HVAC	heating, ventilation, and air conditioning
Hz	Hertz (cycles per second)
IIF	instrument interface flange
in	inch
ITD	Instrument Test Dewar
IVS	instrument vacuum space
JSC	Johnson Space Center
^{o}K	degrees Kelvin
KB	kilobyte
Kg	kilogram
Kpa	kilopascal
KSC	Kennedy Space Center
KVA	kilovolt ampere
KW or Kw	kilowatt
l or lit	liter
L	length
Lb or lb	pound
LHe	liquid helium
lit/sec	liter per second
LN_2	liquid nitrogen
LVDT	linear variable differential transformer

ABBREVIATIONS AND SYMBOLS

ABBREV SYMBOL	TRANSLATION
M or m	meter
max	maximum
MB	megabyte
MB C220	MB C220 vibration exciter
MgFl	magnesium fluoride
MicroVAX	Digital Equipment Corporation computer
MIL STD	Military Standard
min	minute
Mitoc	internal communications system
MLI	multi-layer insulation
mm	millimeter
MOI	moment of inertia
MPMF	Mass Property Measurement Facility
mV	millivolt
NA or N/A	not applicable
NC or N/C	numerically controlled
NASA	National Aeronautics and Space Administration
NASTRAN	finite element modeling program
Ni	nickel
NIST	National Institute of Standards and Technology
nom	nominal
NSI	NSI Technology Services, Inc.
nT	nanotesla
OASPL	overall sound pressure level
ohm	unit of resistance
oz	ounce
pa	pascal
PC	personal computer
PCM	pulse code modulation
pH	measure of acidity
P/L	payload
PLC	programmable logic controller
POI	product of inertia
PRT	platinum resistance thermometer
PRTD	platinum resistance temperature detector
PSD	power spectral density
psi	pounds per square inch
psig	pounds per square inch gauge
PVC	poly vinyl chloride
QCM	quartz crystal microbalance
rad	radian
rad/sec	radians per second
RF	radio frequency

ABBREV SYMBOL	TRANSLATION
RFI	radio frequency interference
RGA	residual gas analyzer
RH	relative humidity
RM or Rm	room
RMS or rms	root-mean-squared
Rolm	GSFC telephone system
RPD	rapid pump down
RPM or rpm	revolutions per minute
RPS or rps	revolutions per second
RTV	room temperature vulcanizer
S. C.	solar constant
SCA	Spacecraft Checkout Area
scfm	standard cubic feet per minute
SES	Space Environment Simulator
SMTF	Spacecraft Magnetic Test Facility
SPL	sound pressure level
sq	square
SSDIF	Spacecraft Development & Integration Facility
STS	Space Transportation System
t	thickness
T	tesla
T	ton
T/C	thermocouple
temp	temperature
TIG	tungsten inert gas
torr	1/760 of a standard atmosphere
TQCM	thermoelectric quartz crystal microbalance
tr	troy
UD	Unholtz-Dickie
UV	ultraviolet
V	volt
VA	volt ampere
Vac	vacuum
VEST	Vehicle Electrical System Test
vol	volume
W or w	watt
W	width
XTE	X-Ray Timing Explorer

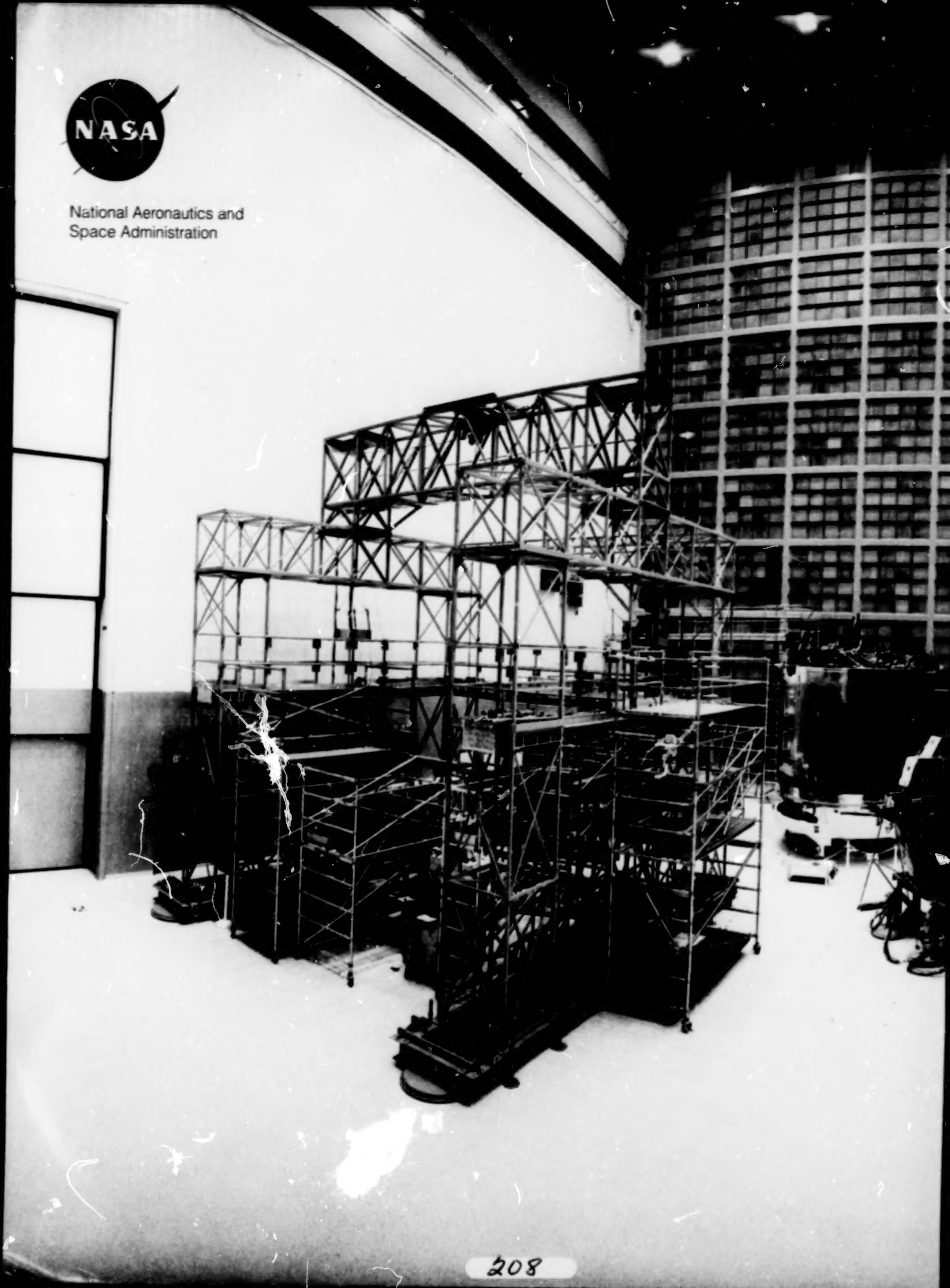
METRIC/ENGLISH CONVERSION FACTORS

METRIC TO ENGLISH UNITS			ENGLISH TO METRIC UNITS		
To Convert From:	**To:**	**Multiply By:**	**To Convert From:**	**To:**	**Multiply By:**
amp/centimeter^2	amp/inch^2	6.45	amp/inch^2	amp/centimeter^2	0.155
amp/decimeter^2	amp/foot^2	9.09	amp/foot^2	amp/decimeter^2	0.11
Celsius	Fahrenheit	[C x (9/5)] + 32	Fahrenheit	Celsius	[F-32] x (5/9)
centimeter	inch	0.3937	inch	centimeter	2.54
centimeter^2	inch^2	0.155	inch^2	centimeter^2	6.452
centimeter^2/liter	foot^2/gallon	0.0041	foot^2/gallon	centimeter^2/liter	245
gram	ounce	.0353	ounce	gram	28.329
gram	pound	0.0022	pound	gram	453.6
gram/centimeter^2	ounce/inch^2	0.228	ounce/inch^2	gram/centimeter^2	4.39
gram/liter	ounce/gallon	0.133	ounce/gallon	gram/liter	7.5
gram/liter	troy ounce/gallon	0.125	troy ounce/gallon	gram/liter	8
kilogram	pound	2.205	pound	kilogram	0.4536
kilogram	ton	0.0011	ton	kilogram	907.2
liter	gallon	0.2642	gallon	liter	3.785
meter	inch	39.37	inch	meter	0.0254
meter	foot	3.281	foot	meter	0.3048
meter^2	foot^2	10.76	foot^2	meter^2	0.0929
meter^3	foot^3	35.31	foot^3	meter^3	0.02832
meter^2/liter	foot^2/gallon	40.82	foot^2/gallon	meter^2/liter	0.0245
micron	microinch	39.4	microinch	micron	0.0254
micron	inch	0.0000394	inch	micron	25400
micron	mil	0.0394	mil	micron	25.4
millimeter	inch	0.0394	inch	millimeter	25.4
newton	pound (force)	0.225	pound (force)	newton	4.45
newton-meter	inch-pound (force)	8.85	inch-pound (force)	newton-meter	0.113
newton-meter	foot-pound (force)	0.7376	foot-pound (force)	newton-meter	1.356
pascal	pound/inch^2 (psi)	0.000145	pound/inch^2 (psi)	pascal	6895
pascal	torr	0.0075	torr	pascal	133.32
watt	horsepower	0.00134	horsepower	watt	745.7

DECIMAL PREFIXES

Prefix	Symbol	Factor
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10^{1}
hecto	h	10^{2}
kilo	K	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}
peta	P	10^{15}
exa	E	10^{18}

National Aeronautics and
Space Administration



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